STATE OF TENNESSEE
STATE GEOLOGICAL SURVEY
GEORGE H. ASHLEY, STATE GEOLOGIST
SUCCEEDED BY
A. H. PURDUE

BULLETIN 14

THE ZINC DEPOSITS OF NORTHEASTERN TENNESSEE

BY

A. H. PURDUE, STATE GEOLOGIST

NASHVILLE, TENNESSEE
1912

BRANDON PRINTING CO.

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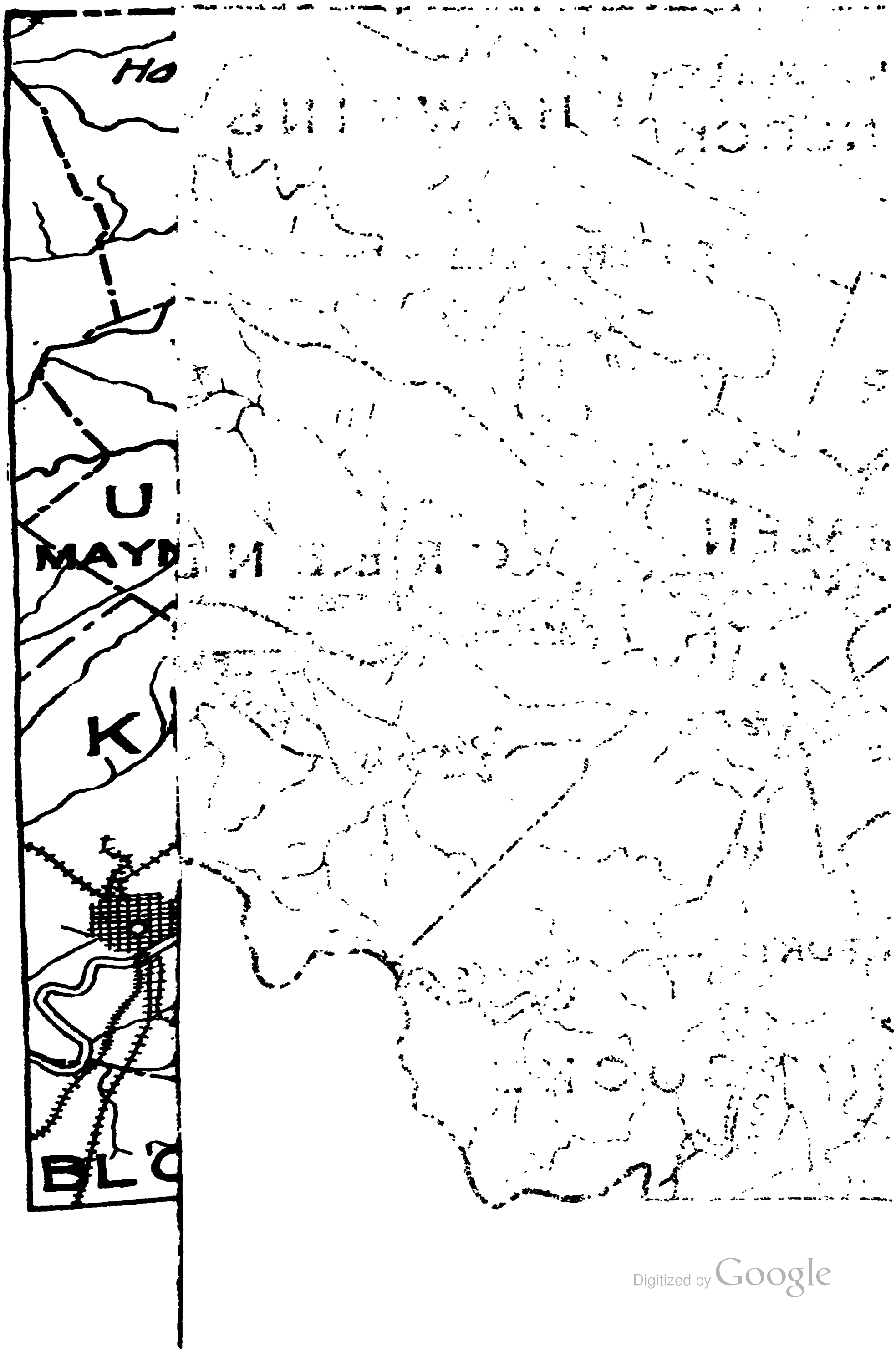
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THE ZINC DEPOSITS OF NORTHEASTERN TENNESSEE

By A. H. Purdue

INTRODUCTION.

The field work for this brief report was done in the latter half of December, 1911, under the direction of Dr. Geo. H. Ashley, then State Geologist of Tennessee, by H. D. Miser and the writer, the former having spent the time from the 14th to near the close of the month, and the latter from the 14th to the 25th. It includes only that part of the State that lies north and east of Knoxville. The limited time that could be devoted to the work prevented the wider observations upon the general geology of the region and the relations of the zinc deposits thereto, that an exhaustive investigation would demand; but it is thought that the observations at and immediately about the prospects and mines of the area covered are fairly complete, except in such ones as were filled with water or which for other reasons were not accessible.

In the course of the work, both during and after the field investigations, free use was made of the writings of Gordon, Osgood, Watson and Keith.* Without the valuable information contained in these writings it would not have been possible for those who made the field observations herein discussed to have done so in the time at their command. Especially were the geological maps and texts of folios Nos. 27, 75 and 118, U. S. Geological Survey, by Mr. Keith, of inestimable value.

LOCATION.

The mines and prospects examined lie north and northeast of Knoxville and are included within a northeast-southwest area, forty miles wide and eighty miles in length. They include what will be known as the Holston River group, located in the valley of Holston River, in Knox and Jefferson counties; the Powell River group, located near the river by this name, in Union and Claiborne counties; the Straight Creek group, located on Straight Creek, Claiborne County; the Fall Branch group, in Sullivan County; and the Jearoldstown group, in Green County. Besides these, there is a prospect three miles east of White Pines, in Jefferson County, known as the Felknor mine. The accompanying sketch map (Plate I) of northeastern Tennessee shows the location of these several groups.

**Extracts D and G, Bull. No. 2*, Geol. Surv. of Tenn.; *Trans. Am. Inst. Min. Eng.* Vol. XXXVI, pp. 681-737; *Bull. No. 225*, pp. 208-213, and *folios Nos. 27, 75 and 118*, U. S. Geol. Surv.

GENERAL GEOLOGY.

Topography and drainage.—The controlling surface features of the area within which the zinc deposits occur are northeast-southwest ridges, with their intervening valleys. The ridges, which lie in the middle part of the area, stand up from a few hundred to more than 1,000 feet above the surrounding country, and many are properly called mountains. Beginning with the south and naming them in their order northward, the principal streams are Holston, Clinch, and Powell rivers. All these have a southwesterly course and empty into the Tennessee. The valley of the Holston is wide and open, and is occupied by well rounded hills from 1,000 to 1,400 feet above sea level. Clinch River flows through and follows the course of the ridgy part of the area, winding its way from one ridge to another, or through ridges, forming water gaps, and for the most part lying in a narrow valley. Powell River lies between the ridges of the area and Cumberland Plateau to the northwest.

Southwest of Tazewell, the water divide between Clinch and Powell rivers is poorly defined. The area between these streams is much broken, the hills being promiscuously arranged, with steep, tough soil-covered slopes, and with crests from 200 to 500 feet above the intervening valleys.

A striking feature of this area is the great number of large sink-holes. Many of these have the usual funnel-shaped form common to such depressions, and may be expected upon either flats or slopes; but there are many that assume the shape and size of erosion valleys. The length of such is measured in miles. They are several hundred feet deep, and have large tributary valleys entering from the sides. These are all depressions of solution, formed by the work of ground-water upon the limestone of the area, and the drainage into them passes off underground. Even in the formation of the valleys which open out into the streams, solution has been a factor at least equally important with erosion.

Despite the very steep slopes, this area is covered with red, fertile, residual soil, from a few feet to 60 feet deep. Only here and there are rock ledges to be seen on the hillsides, nearly all of which may be cultivated, and most are. This heavy mantle of soil has interfered greatly in prospecting for zinc, having, except where drills have been used, restricted it to the outcrops of zinc-bearing rocks in ravines.

Age and description of the ore-bearing rocks.—The geology of the zinc area of East Tennessee has been worked out by Mr. Arthur Keith, of the U. S. Geological Survey, and published in folios Nos. 25, 27, 75 and 118 of that bureau. Mr. Keith finds that this portion of the State contains rocks of all ages from Cambrian to Carboniferous, inclusive. But one of these formations, the Knox dolomite, is known to carry ores of zinc. According to Mr. Keith, the lower part of this formation is of Cambrian, and the upper part of Ordovician age and is described by him* as follows:

"The lower part contains middle Cambrian and the upper part Silu- "rian (Ordovician) fossils, largely gasteropods; but it is impossible to "draw any boundary between the two parts of the formation.

"The Knox dolomite is the most important and widespread of all the "valley rocks. Its name is derived from Knoxville, Tennessee, which "is located on one of its areas. The formation consists of a great series "of blue, gray and whitish limestone and dolomite (magnesian limestone) "most of which is very fine grained and massive. Many of the beds are "banded with thin, brown, siliceous strata. In the lower part of the "formation, there are also many white and sandy layers. Over large areas, "notably near Clinch and Powell rivers and north of New Market, these "layers are coarsely crystalline, and in fact, marble. All varieties are "to be found, from slightly siliceous marble to calcareous sandstone. "The sandstones outcrop along the rivers in prominent cliffs. Included "in the beds of limestone and dolomite, are nodules and masses of black "chert, locally called 'flint,' and their variations form the principal "changes in the formation. The cherts are most conspicuous in the lower "part of the formation, and in places, by the addition of sand grains, "grade into thin sandstone."

It will be noticed from the above description that the Knox dolomite is the most important formation of the valleys; but as it does not occur in the prominent ridges, these should be avoided in prospecting for zinc. The area of this formation as it outcrops at the surface, may be recognized by its valley topography, the large number of sink-holes, the rounded hills, and the thick mantle of red soil, which contains fragments of flint in greater or less quantities.†

Structure of the rocks.—The rocks within the zinc area are all folded, the direction of the folds being northeast and southwest. Along certain belts the folding has been rather extensive, and in such the rocks dip at high angles. Along others, the folding has been but slight. In such, the rocks lie horizontal or dip at low angels. The belt of greatest folding is the one of ridges, described under the head *topography*. Along this belt, there was not only folding, but faulting. The faults have the same direction as the folds, and along them the rocks on the southeast side have been shoved up on those of the northwest side. Figure 1 will give a general idea of the structure of the area.

**Folio No. 75*, U. S. Geol. Surv.

†Those prospecting for zinc should make constant use of the geological maps in folios Nos. 27, 75 and 118, U. S. Geol. Survey. These can be had for 25 cents each. Address Director, U. S. Geological Survey, Washington, D. C.

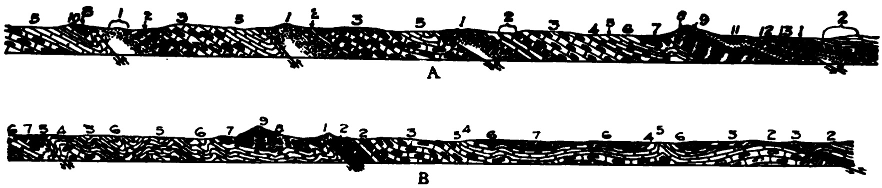

Fig. 1. A. Northwest-southeast section passing northeast of Maynardville, Union County.
B. Northwest-southeast section near Strawberry Plains, Jefferson County.

13. Newman limestone.
12. Grainger shale.
11. Chattanooga shale.
10. Rockwood formation.
9. Clinch sandstone.
8. Bays formation.
7. Sevier shale.
6. Tellico sandstone and Moccasin limestone.
5. Chickamauga limestone.
4. Holston marble in Chickamauga limestone.
3. Knox dolomite.
2. Conasauga shale.
1. Rome formation.

(Keith)

Northeast of the belt of greatest folding, between Clinch River and Cumberland Plateau, there is a belt in which the disturbance has been slight; and a similar one lies in the valley of Holston River, southeast of the belt of greatest disturbance. Where the folding is greatest, the formations outcrop in narrow northeast-southwest strips, and where least, a single formation may cover an area several miles wide. This is especially true of the thick Knox dolomite, the zinc-bearing formation of the area.

The above description applies to what might be termed the gross structure of the area. Besides these main features, there are the smaller, but as relates to ore deposition the more important ones. Among these are small folds, faults, brecciated beds and shearing planes. Small gentle folds as well as faults of but little displacement may be expected anywhere. In the great movement that produced the major structural features, certain beds of the Knox dolomite were crushed and broken into small blocks and pieces, and these tilted in all conceivable positions. Also accompanying this movement, there was a great deal of shearing along some of the bedding planes, which resulted in the fracture of one or both of the contiguous beds. It was in such fractured rock, whether adjacent to fault planes, shearing planes, or consisting of entire beds, that the ores of zinc were deposited, along with other minerals. These minerals, economic and useless, served as cementing material, which bind the crushed fragments together, producing the breccia that is so common in the Knox dolomite.

Ore horizons.—Whether or not the ore occurs at definite horizons or geological levels in the Knox dolomite, has not yet been determined. The group of mines and prospects on Powell River, collectively known as the "Lead mine bend mines," certainly are not far above the base of the Knox dolomite; and while it is inferred from the nature of the rocks in which they occur, that the other prospects of the Powell River group occur at the same horizon, the writer has not been able definitely to establish such. The deposits of the Straight Creek group are near the base of the Knox dolomite. The mines and prospects of the Holston River group from Knoxville to Mascot appear to be located at a well-defined horizon some distance below the top of the formation, and those at New Market probably occur at the same geological level. The prospect south of White Pines, in Jefferson County, and those about Fall Branch in Sullivan County, and Jearoldstown in Green County are apparently nearer the top of the Knox dolomite than those of the Holston River group.

NATURE OF THE ORES.

The common ores of zinc are sphalerite* and smithsonite. Less common ones are calamine, zincite, franklinite and willemite. Other names for sphalerite are blende, jack and black-jack or rosin-jack, depending upon the color. In composition, sphalerite is zinc sulphide, with the chemical formula ZnS. Its theoretical composition is 67 per cent zinc and 33 per cent sulphur, but in nature it contains impurities which consist of one or more of several elements. Consequently, the ore never carries the full theoretical amount of zinc. The common elements that enter as impurities are iron, silica, magnesia and calcium.

An idea of the per cent of metallic zinc to be expected in sphalerite may be had from the following tables:

Analyses of sphalerite from Missouri.†

Location.	Zinc.	Sulphur.	Silica.	Iron.	Calcium.
Joplin, Porter mine	65.92	....	0.25	0.32	0.509
Joplin, Leadville mine	64.87	....	1.41	0.37	0.723
....	61.963	....	....	0.588	0.000
Granby, Bellew mine	64.67	....	2.05	0.53	....
Granby	61.934	31.269	2.552	0.788	Trace.

*Wurzite is an ore of zinc of the same composition as sphalerite, but it crystallizes in the hexagonal system, while sphalerite crystallizes in the isometric system. Wurzite is not an important ore, though it may be commonly associated with sphalerite.

†Mo. Geol. Surv., *Lead and Zinc*, Pt. II, p. 450.

*Analyses of sphalerite from Arkansas.**

Mines.	Zinc.	Sulphur.	Silica.	Iron.	Magnesia.
Yankee Boy	65.88	31.77	0.10	0.62	0.14
Hiawatha	66.27	32.53	0.21	0.39	Trace
Governor Eagle	64.48	32.16	1.88	0.26	0.00
Panther Creek	65.88	32.30	0.00	0.49	Trace
Prince Frederick	65.68	33.33	0.09	0.15	0.03
Hunt, M. and B.	58.68	20.36	0.10	0.20	0.10
St. Joe	65.73	32.92	0.11	0.15	0.08
Bear Hill	66.46	32.30	0.25	0.15	0.20

Analyses of sphalerite from Tennessee.†

Fall Branch.

Moisture	0.00	per cent.
Metallic zinc	63.88	per cent.
Iron	.55	per cent.
Insoluble residue	.68	per cent.
Sulphur	31.83	per cent.
Manganese	.007	per cent.
Copper	Trace.	
Lead	Trace.	

Grasselli Chemical Co., New Market.

Moisture	.09	per cent.
Metallic zinc	65.76	per cent.
Iron	.22	per cent.
Insoluble residue	.62	per cent.
Sulphur	32.20	per cent.
Manganese	.007	per cent.
Copper	Trace.	
Lead	Trace.	

Leadvale.

Moisture	.03	per cent.
Metallic zinc	61.90	per cent.
Iron	.44	per cent.
Insoluble residue	1.56	per cent.
Sulphur	30.41	per cent.
Manganese	.007	per cent.
Copper	Trace.	
Lead	Trace.	

American Zinc Company's mine, Mascot.

Moisture	.06	per cent.
Metallic zinc	62.00	per cent.
Iron	.26	per cent.
Insoluble residue	4.64	per cent.
Sulphur	30.46	per cent.
Manganese	.007	per cent.
Copper	Trace.	
Lead	Trace.	

**Ann. Rept. Geol. Surv. of Ark.*, 1892, Vol. V, p. 10.

†The analyses of all the Tennessee zinc ores, published in this bulletin, were made in the Brown Laboratories, Inc., Nashville, Tenn.

New Prospect mine.

Moisture	.05	per cent.
Metallic zinc	34.32	per cent.
Iron	.49	per cent.
Insoluble residue	.86	per cent.
Sulphur	22.99	per cent.
Lead	40.66	per cent.
Copper	Trace.	

Smithsonite, the other of the two common ores is the carbonate of zinc, with the formula $ZnCO_3$. Theoretically, it contains 64.8 per cent of ZnO (=52.01 per cent of metallic zinc) and 35.2 per cent of CO_2. The accompanying tables give analyses of smithsonite:

*Analyses of smithsonite from Arkansas.**

	Morning Star.	Legal Tender.
Zinc oxide	64.31[1]	62.20[2]
Carbon dioxide, CO_2	34.93	33.86
Water, H_2O	0.58	2.30
Silica, SiO_2	0.10	0.02
Magnesia, MgO	0.03	0.18
Lime, CaO	0.90	1.25
Iron and alumina, Fe_2O_3 and Al_2O_3	0.12	0.21
Cadmium, Cd	Trace.	Trace.

Analyses of smithsonite from Missouri. †

	ZnO.	CO_2	Ferrous oxide.	Ferric oxide.	....	Alumina	cupric oxide.
Dade County—							
Corry mines	54.484	31.69	1.20	....	5.62	....	....
New mines	59.09	....	....	....	3.23	....	....
Granby	63.02	34.58	....	....	1.21	....	....
Washington County—							
Hopewell	53.997	24.302	1.039	4.263	....	.632	.052

	Lime	Mg.	S.	H_2O	Insol. Residue.	Total
Dade County—						
Corry mines	.45	.41	....	.16	7.39	99.77
New mines	1.20	.28	....	....	....	....
Granby	....	....	....	....	1.22	100.03
Washington County—						
Hopewell	2.393	.546	.242	2.414	8.51	98.773‡

**An. Rep., Geol. Surv. of Ark.*, 1892, Vol. V, p. 11.

[1]Equals 51.62 per cent metallic zinc.

[2]Equals 49.52 per cent metallic zinc.

†Mo. Geol. Surv. *Lead and Zinc*, Vol. II, p. 452.

‡Trace of PbO; CdO, .173; Sb_2O_3, .170.

*Analyses of smithsonite from Tennessee.**

New Prospect mine.

Moisture	.31 per cent.
Zinc	41.10 per cent.
Iron	1.10 per cent.
Insoluble residue	1.40 per cent.
Calcium carbonate	.89 per cent.
Manganese	.036 per cent.
Magnesium carbonate	Trace.
Copper	Trace.
Lead	Trace.
Equivalent to zinc carbonate	94.16 per cent.

Straight Creek.

Moisture	.34 per cent.
Zinc	48.11 per cent.
Iron	3.63 per cent.
Insoluble residue	1.46 per cent.
Calcium carbonate	.44 per cent.
Magnesium carbonate	Trace.
Manganese	.022 per cent.
Copper	Trace.
Lead	Trace.
Equivalent to zinc carbonate	92.25 per cent.

Grasselli Chemical Company's mine, New Market

Moisture	.32 per cent.
Zinc	45.03 per cent.
Iron	.33 per cent.
Insoluble residue	10.60 per cent.
Calcium carbonate	.50 per cent.
Magnesium carbonate	Trace.
Manganese	.022 per cent.
Copper	Trace.
Lead	Trace.
Equivalent to zinc carbonate	86.36 per cent.

While sphalerite and smithsonite constitute most of the zinc ores placed on the market, calamine is not uncommon. The formula for this ore is $(Zn, OH)_2 SiO_3$. Theoretically, it contains 54.2 per cent of metallic zinc, 25 per cent of SiO_2 (silica), and water. This ore probably occurs in limited amount wherever smithsonite is found in Tennessee, and in the prospect three miles southwest of Leadvale, in Jefferson County, it is the principal ore. Franklinite and willemite are not known in Eastern Tennessee, and zincite occurs only sparingly.

*These analyses were made by the Brown Laboratories, Inc., Nashville, Tenn.

Analysis of calamine from Leadvale, Tennessee.

Moisture	.77	per cent.
Metallic zinc	47.36	per cent.
Iron	.44	per cent.
Insoluble residue	28.86	per cent.
Alumina	1.04	per cent.
Combined water	8.54	per cent.
Lime	.10	per cent.
Magnesia	Trace.	
Manganese	.007	per cent.
Copper	Trace.	
Lead	Trace.	

The sphalerite in the Holston Valley, even from below water level, is so nearly free from color that one accustomed to this ore in the Central and Western states will at first fail to recognize but little of it in hand specimens and on mine faces. That from other localities is darker and more easily detected.

MODE OF OCCURRENCE OF THE ORES.

The zinc of the workable deposits of East Tennessee, like most mineral deposits, was not originally put down as it now occurs, but was brought from other parts of the rocks by ground-water and concentrated in favorable places. Such places constitute the present ore bodies.

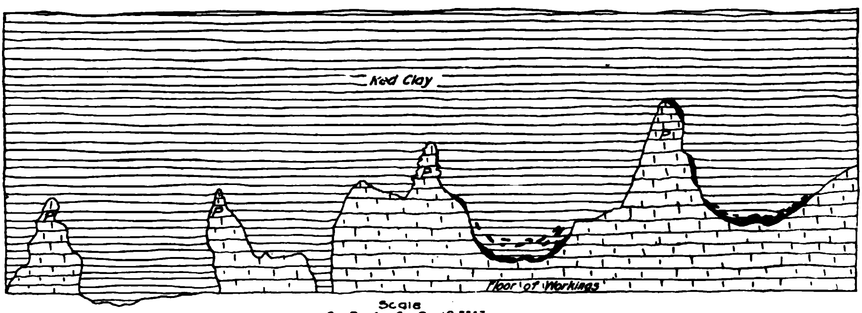

Fig. 2. A section (partly ideal) of the Grasselli Chemical Company's mine at New Market.
Black=ore; P=pinnacles.

Occurrence of smithsonite and calamine.—The smithsonite and calamine of East Tennessee occur in the residual red clay soil overlying the Knox dolomite. The soil is everywhere thick, in many places probably exceeding 75 feet. The surface of the underlying limestone is very uneven, consisting of irregularly shaped columns or "pinnacles" from a few feet to 30 feet or more in height, with intervening basins. The ores occur (Fig. 2) as lumps and earthy matter in the clay and as crusts on the surface of the limestone. The most productive parts are the pockets or basins, though much ore is obtained from the tops of the pinnacles. The ore in the clay is in rather well-defined lines which conform to the surface of the rock below. According to the writer's observations, the productive lines are near the limestone, though he was informed by the miners that chunks of smithsonite may occur anywhere in the clay. The ore adhering to the rock is in the form of masses and thin crusts. While it may occur on the sides of the pinnacles, the richest parts are in the basins or as pinnacle cappings.

It must not be understood that all parts of the rock or all basins of clay are productive. On the contrary, many of the pinnacles and basins are barren of ore, and there is no way to determine what parts carry ore and what ones do not except by exploitation.

Occurrence of sphalerite.—The sphalerite occurs in and associated with the brecciated dolomite and limestone of the Knox formation. As above stated there appears to be a fairly well-defined horizon of this ore near the base of the formation, and the mines and prospects in the Holston Valley are thought to be not far from the top, and at approximately the same geological level. On account of the thick mantle of soil, prospecting for this ore is difficult, and can be satisfactorily done only with the drill. Most of the sphalerite occurs as a part of the cementing material of the breccia, but some of it is in beds that have been removed by solution and replaced by other material. In such cases the sphalerite occurs as small grains disseminated through the rock, and as indistinct, poorly defined veins.

Associated minerals.—The minerals with which sphalerite is associated as the cementing material in the Holston Valley ore are secondary (vein) dolomite and calcite, the former being by far the most common. The sphalerite is usually flaky and may occur in grains distributed through the dolomite or calcite, or as veins in these, or between them and the rock, as shown in Fig. 3. In the Powell River and Straight Creek ores the associated minerals are galena, cerussite and pyrite. Galena has the formula PbS, and is the most common ore of lead. Cerussite is a gray mineral with the formula $PbCO_3$, and is formed from galena much as smithsonite is formed from sphalerite, a process later to be described. In the mines here referred to it commonly occurs as a coating inclosing crystals of galena. Pyrite is a brassy yellow mineral that occurs in cubes whose faces are striated. It has the formula FeS_2 and is commonly called "fool's gold". In Sullivan and Jefferson counties, the principal minerals associated with the sphalerite are dolomite, calcite and barite, though the last two exist in but small amount. Galena occurs sparingly.

There is some iron pyrite and occasional crystals of chalcopyrite. The latter resembles pyrite, and is one of the ores of copper, with the formula $CuFeS_2$. In some of the prospects in the vicinity of Fall Branch, there are small amounts of a dark mineral that looks like graphite, but which is a petroleum product very similar to the one known as grahamite.

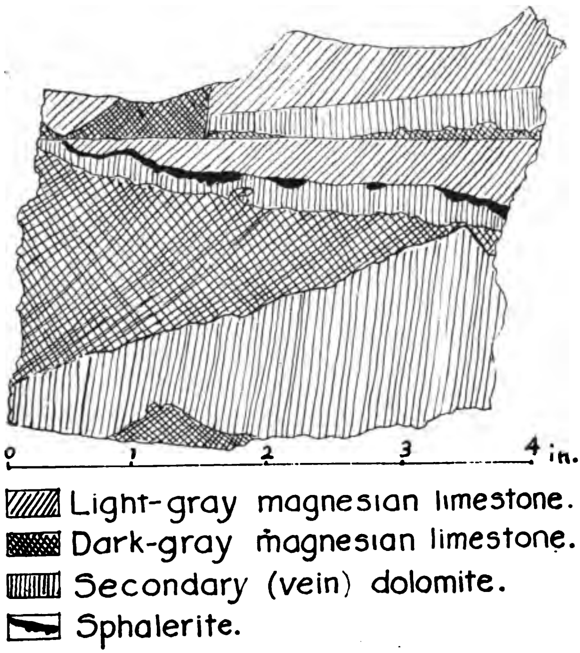

Fig. 3. Sample of ore in brecciated rock from "Old mine," near New Market.

HISTORY OF THE ORES.

Sphalerite.—The original source of all mineral products, as well as of the stratified rocks, was igneous rocks. But while this is true, many minerals and stratified rocks may have been weathered, removed, and redeposited many times since their first derivation from the parent rock. As has been shown by Watson,* there is no reason for believing that the zinc deposits of the Tennessee-Virginia areas were derived directly from igneous rocks, for such rocks are unknown within the region. In the same connection, Watson further calls attention to the fact that apparently the structual conditions are as favorable for the occurrence of zinc in other formations of the area as in the Knox dolomite, but no other formation of the region is known to contain zinc. It therefore seems

*Lead and zinc deposits of the Virginia-Tennessee region. Trans. of Am. Inst. of Min. Eng. Vol. XXXVI, pp. 681-737.

probable that the zinc was deposited with the Knox dolomite, and at rather definite horizons in that formation As first deposited it was but sparingly distributed through the rock, and was subsequently concentrated by moving ground-water along zones of fracturing that resulted from crustal movement. The fracturing accompanied the folding, faulting and shearing above discussed.

The period of greatest folding of the area was that which followed Carboniferous times, but there were other periods of movement much later. During the first mentioned period, the Knox dolomite was under the weight of many hundred feet of overlying younger rock, but before the subsequent movements took place these had been in large part removed by erosion; and though the later movements were milder than the earlier one, the suggestion that the crushing preparatory to ore deposition took place while these were in progress, instead of at the time of the earlier more violent ones, must be entertained; for it is not easy to conceive how the extensive crushing to which the breccias testify could have taken place under the great burden of overlying rock that was present, at least in the early part of the first movement. Because in this crushing and rearrangement of the parts of the beds, many fragments took their position with their longest direction at an angle to the bedding planes, which meant a thickening of the beds. It appears that the great weight of the rocks that formerly overlaid the beds bearing the zinc, would have held all of them intact during the process of folding.

Such parts as were crushed by the crustal movements, invited a flow of water far in excess of what was possible in other parts. The groundwater, slowly moving through other parts, dissolved the zinc which was sparingly distributed, presumably in the Knox dolomite, and brought it in solution to the fractured parts, where it was precipitated. If the solution took place near the surface, in the oxidized zone, the zinc sulphide (ZnS) had been oxidized, and the zinc in solution was in the form of the sulphate ($ZnSO_4$) or the carbonate ($ZnCO_3$). It is probable that both were present, with the sulphate predominating. The zinc of the sulphate solution was carried below by descending waters and precipitated, in part as the sulphide, in part as the carbonate and under favorable conditions, in part as the silicate. If deposited as the sulphide, the zinc completed the circle from its original form of the insoluble ZnS through the soluble $ZnSO_4$ and back again to the insoluble ZnS. If the solution was in the form of the carbonate, the alteration was from the ZnS through the $ZnCO_3$, back to the ZnS. In this case, probably under most conditions only a part of the zinc was deposited as the sulphide, and the remainder as the carbonate and silicate.

The most common precipitating agent of the zinc from the sulphate solutions back to the insoluble sulphide doubtless was iron sulphide, the latter mineral acting as a reducing agent of the zinc sulphate, as shown in the following equation:

$$ZnSO_4 + FeS = ZnS + FeSO_4.$$
or
$$ZnSO_4 + FeS_2O = ZnS + FeSO_4 + SO_2*.$$

But where organic matter was present, this may also have acted as a precipitating agent. As elsewhere noticed in this bulletin, organic matter occurs as one of the hydrocarbon compounds in limited amount in the mines of the Fall Branch group.

It is probable that the sulphide of iron was the principal precipitating agent of the zinc from not only sulphate solutions, but was also the agent in precipitating that mineral from the carbonate solutions, in those cases where the zinc from such was deposited as the sulphide. The reaction as given by Van Hise is shown in the following equation:†

$$ZnCO_3 + FeS = ZnS + FeCO_3.$$
or
$$ZnCO_3 + FeS_2 + O_2 = ZnS + FeCO_3 + SO_2.$$

Probably but little of the zinc of the carbonate solution was precipitated as the sulphide, but most of it as the carbonate, presumably after the manner of the formation of concretions, whatever that process may be.

It was stated above that a part of the zinc of zinc sulphate solutions was deposited as zinc sulphide, a part as zinc carbonate, and a part as the zinc silicate. Where limestone is abundant, as in East Tennessee, the conditions are more favorable for deposition of the carbonate than the sulphide or the silicate. The waters from the oxidized zone move downward with the zinc sulphate in solution, and flow over the surface of the limestone beneath. There results the reaction between the solution and the limestone represented by the following equation:

$$ZnSO_4 + CaCO_3 + 2H_2O = ZnCO_3 + CaSO_4.2H_2O.$$

If silica is present in the solution, a zinc silicate may be formed. After the carbonate and possibly the silicate have been deposited, a part of the zinc remaining in the solution may be deposited as the sulphide, by some metallic sulphide or organic matter acting as a reducing agent, as above discussed.

It must not be understood that all the concentration of the zinc ores took place by the downward movement of water from the oxidized upper part of the rocks and rock mantle. The carbonate and silicate ores were so

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*C. R. Van Hise, A Treatise on Metamorphian, *Monograph*, U. S. Geol. Surv., p. 1152.

†Loc. cit.

concentrated. But the sulphide ore was concentrated in fractured parts of the rocks mainly by water moving through the rocks below the oxidized zone. In the zone of oxidation, the solutions were attributable to the alteration of the zinc from the insoluble sulphide to the soluble sulphate. Below the level of ground-water, oxidation takes place only in a limited way so that but a small amount of the comparatively insoluble zinc sulphide is there altered to the soluble sulphate. It follows that the agents that work effectively in throwing the zinc into solution are other than ground-water, which is the solvent in the oxidized zone.

It is known that sulphides of the metals, zinc sulphide included, are soluble in sodium sulphide, and it is thought that the latter is produced by nature* in sufficient quantities to perform the work of solution necessary to concentrate ores of the metals in the unoxidized zone. In the concentration process, the ground-water carrying the solutions may have flowed laterally, upward or downward, depending upon the head under which it moved.

It must not be inferred that all parts of the fractured zone were traversed by zinc-bearing solutions. Many parts doubtless never were reached by such solutions, and others were occupied only a short time or by very dilute solutions, either of which conditions would result in only meagre deposits. Only those favored parts that were occupied by moving, zinc-laden water under conditions favorable to precipitation contain workable deposits.

As Watson has already stated,† the deposition of the zinc sulphide and the associated secondary dolomite and calcite appear to have been contemporaneous. In some cases the blende band occupies one side of a vein with dolomite on the other, in others it is inclosed by dolomite, in others a portion of it adheres to the rock while another part is inclosed, and yet in others it is irregularly distributed through the dolomite. Likewise, in the hand specimens examined containing sphalerite and galena, the evidence is in favor of contemporaneous deposition of these two minerals. This is shown in Fig. 4, in which the edges of the sphalerite and galena crystals are interlocked in such manner as plainly to indicate that taking the process as a whole the two minerals were formed at the same time, though individual crystals of each were perfectly formed before they were inclosed by the other.

The altered ores.—The original of the common ores of zinc is sphalerite, or zinc blende. Smithsonite, or carbonate ore, and calamine, or silicate ore, are secondary. The last two are commonly spoken of by both miners and geologists as oxidized ores. They are derived from the sphalerite in the zone of oxidation, which zone is composed chiefly of those rocks near

*Van Hise, cit. pp. 1106-1107.
†Loc. cit.

the surface and above the level of saturation by water. It is here that the agents of rock weathering work most rapidly and effectively. If the rock be sandstone or shale, it is broken down into sandy soil in the one case or clay soil in the other. If it be limestone, the calcium carbonate ($CaCO_3$) is carried away in solution, and the insoluble part is left as a residue of clay soil. The latter process is what took place over the area of the Knox dolomite, and such is the origin of the mantle of red soil that everywhere covers the formation.

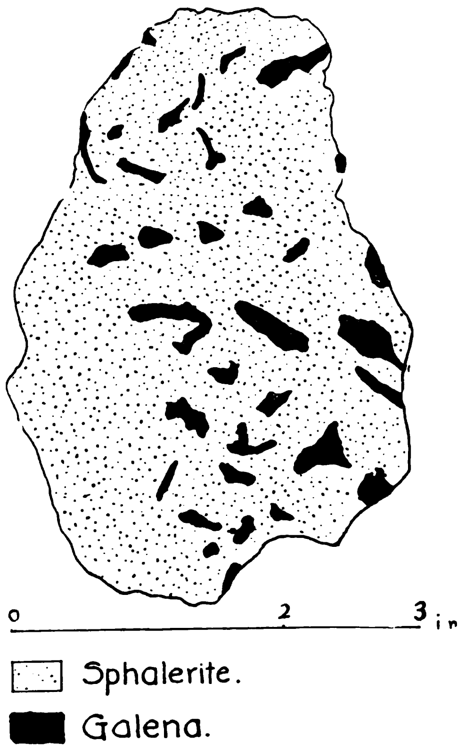

Fig. 4. Specimen of galena and sphalerite.

In the weathering processes the sphalerite of the Knox dolomite was altered along with the remainder of the rock, the first change being that from zinc sulphide (ZnS) to zinc sulphate ($ZnSO_4$). The sulphate is soluble in water, and was taken up by that agent as it moved through the rocks. In this condition a portion of the zinc escaped in the water of springs and seeps, a portion was carried downward into the openings of the rocks below and redeposited probably as sphalerite, and a third portion was carried to the surface of the underlying limestone and deposited as smithsonite. The latter was deposited from the chemical reaction between the zinc sulphate and the calcium carbonate of the limestone. The reaction is represented by the following equation:

$$ZnSO_4+CaCO_3+2H_2O=ZnCO_3+CaSO_4.2H_2O.$$

The $ZnCO_3$ is smithsonite, or zinc carbonate. Unlike the zinc sulphate, it is ordinarily insoluble and for that reason it is thrown down as an ore. That part of the equation represented by $CaSO_4.2H_2O$ is gypsum, which was carried away by the water in solution.

In case the solution containing zinc sulphate becomes mixed with solutions containing silica, calamine, or zinc silicate may be formed after the following reaction:

$$2ZnSO_4+3H_2O+SiO_2=(ZnOH)_2\ SiO_3+2H_2SO_4.$$

The calamine is represented in the equation by $(ZnOH)_2\ SiO_3$.

That smithsonite is derived from sphalerite may be observed in hand specimens taken from almost any mine where smithsonite occurs. In such specimens, the smithsonite is on the outside, that having been first affected by the oxygen and carbon dioxide. In this case, the reactions are somewhat different from what they are when the zinc sulphate flows over limestone, and may be represented as follows:

$$ZnS+4O=ZnSO_4$$
$$ZnSO_4+H_2O+CO_2=ZnCO_3+H_2SO_4.$$

If the amount of carbon dioxide and free oxygen in the water are practically equal, the zinc carbonate is formed simultaneously with the oxidation of the zinc sulphide, and the former sticks closely to the latter; but if oxygen is in excess of carbon dioxide, the zinc sulphide is removed faster than the zinc carbonate is formed and small cavities or vugs occur between the two. Both of these conditions are common in cabinet specimens.

Galena, or the sulphide of lead, has the formula PbS. In the zone of oxidation, this undergoes changes similar to those that take place in the sulphide of zinc, though much more slowly, for the lead sulphide is much the more stable of the two. The reactions may be represented as follows:

$$PbS+4O=PbSO_4$$
$$PbSO_4+H_2O+CO_2—PbCO_3+H_2SO_4.$$

As previously stated, the $PbCO_3$ is a light-gray, earthy mineral called cerussite, and may often be seen as a thin coating over crystals of galena, the outside part of which has been altered. If galena and zinc blende occur together, as they do in the Powell River group of mines, the former may remain wholly unaltered, or only slightly altered, while the latter is entirely altered to smithsonite. Figure 4 would represent this combination of minerals, if smithsonite be thought of as occurring in place of the sphalerite. Such association of these two minerals is common near the surface.

A similar transition to that observed in the hand specimen in which the ore changes from smithsonite on the outside to sphalerite within, is observed on a large scale in passing downward through ore bodies where smithsonite occurs at the top. The upper part, having been more and longer exposed to atmospheric agencies than the lower part, usually is largely or completely altered from sphalerite to smithsonite or calamine; but with depth, the amount of the altered ore decreases while that of the sphalerite increases, until the latter constitutes all the ore. Similar changes occur in the ores of other metals, and are familiar to miners.

In eastern Tennessee, both the sphalerite and the oxidized ores occur, and both are or have been produced and marketed. The oxidized ores, mainly smithsonite, are usually mined in open pits. As above stated, most of them are taken from the residual soil and from the surface of the underlying limestone upon which they occur as a crust, or in irregular masses. Only a small amount occurs within the limestone. Figure 2 will give an idea of the mode of occurrence of the ore in the mines of the Grasselli Chemical Company, at New Market, and is typical of the entire area. The figure shows the very uneven character of the limestone surface as it everywhere exists beneath the mantle of soil. In the removal of the limestone by ground-water, that agent was not in all parts equally abundant. Those parts along which it flowed in greatest quantity were most rapidly removed, the intervening ones having been left as columns or pinnacles standing up in the clay.

Concentration of the oxidized ores.—As the oxidized ores are derived from sphalerite, it follows that they occur only in those parts of the residual clay that overlie sphalerite deposits in the Knox dolomite. No analyses of the Knox dolomite are at hand, but it is thought that 20 per cent would be a very liberal allowance for its insoluble material. Upon such an assumption, 40 feet of residual clay would represent 200 feet of limestone, not considering what has been removed by erosion. The amount so removed probably several times exceeds the remaining part, so the oxidized ores within the clay are the concentrates from the several hundred feet of sphalerite that was in the rocks that have been removed; but it must be remembered that not all the original sphalerite is represented in these ores, for as above stated a part of the zinc was lost by having been carried away in solution and a part was redeposited in the rocks below, as sulphide or blende.

The deposition of the smithsonite on the limestone was produced by the reactions between the zinc sulphate solution and calcium carbonate of the limestone, as shown on p. 17. By reference to Fig. 2, p. 13, it will be seen that the richest deposits occur in the pockets between the pinnacles. The reason for this will be readily understood when it is remembered that some of these pockets were in important lines of zinc-laden ground-water flowage, and that water flowed down the sides of the pinnacles into all of them. As the water flowed down the sides of the columns, it is easy to understand why the ore on their sides occurs as a thin coating; but the rather rich deposits that not infrequently occur at the tops of the pinnacles is not so easily understood. It has been suggested by Prof. A. A. Steel*, of the University of Arkansas, that these deposits formerly were in pockets, and that the smithsonite, being less soluble than the limestone, protected the portion beneath and remained as the capping of the pinnacle thus formed. The supposed process is shown in Fig. 5.

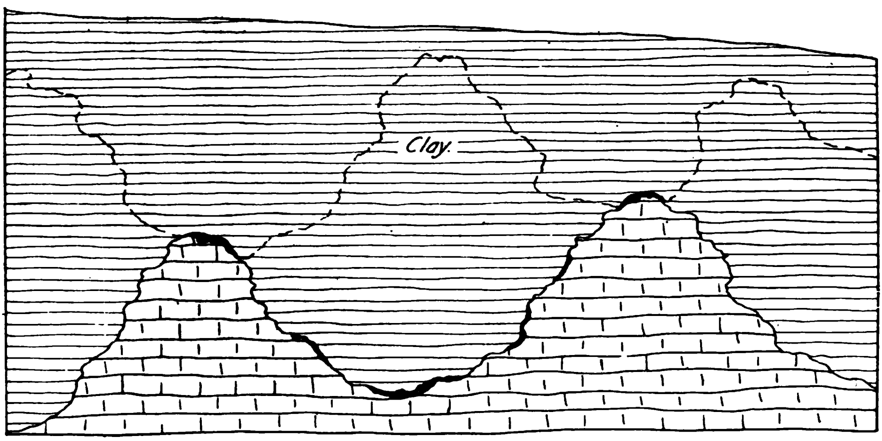

Fig. 5. Showing the possible origin of rich ore deposits capping pinnacles. The broken line represents the supposed former profile of the rock surface.

While many of the pinnacles and pockets are rich in ore, others contain none. As the rock is the same in the barren and ore-laden parts, the absence of ore in the former must be attributed to the absence of zinc solutions in and about them; and the absence of zinc solutions probably is attributable to the absence of zinc ore above such parts, for the movement of the water was mainly downward till it reached the rock surface beneath the soil.

While smithsonite is quire stable, it is not to be supposed that it has always escaped solution. On the other hand, there is reason for believing that the residual smithsonite of Tennessee has been dissoved and re-

*Verbal communication.

precipitated, possibly many times. The agents of solution presumably were organic acids and carbon dioxide. So far as the writer's observations go, smithsonite does not occur near the surface of the soil and its absence is thought to be due to removal by the organic acids there present. The large chunks of smithsonite that are reported by the miners as sometimes occurring in the clay, probably were formed by the solution and reconcentration of smithsonite, by a process similar to that from which concretions are formed.

PROSPECTING.

While it is not necessary for a prospector to be a geologist, it is eminently desirable that in searching for ore, certain elementary geological conditions should be observed; for such observance not only will result in the discovery of more ore than otherwise would be found, but also will save a great deal of time and money. The most important of these conditions are presented in the following brief discussion:

Faults.—As much of the zinc ores of East Tennessee occur on or near faults, it is necessary for the successful prospector to be able to recognize a fault. The essential conception of the common type of fault is that of a fracture crossing the rock beds, which are displaced so that those on opposite sides of the fracture do not match up. The fracture may be perpendicular to the beds, but usually it is inclined at a greater or less angle to them. In some cases it is so much inclined that it is practically if not quite parallel with the bedding. In such there was shearing between the beds, which may have resulted in their fracturing, as in New Prospect mine on Powell River, later to be described. The displacement in faults may be only a fraction of an inch, and it may be as much as several thousand feet. Often, not only different beds, but different geological formations that formerly were separated by great vertical distances are brought to a level by displacement in faulting.

To recognize the geological formations, the prospector should provide himself with the best geological map of the area to be investigated, and use this in conjunction with the descriptions of the formations that accompany the map, not only in the office, but while at work in the field. By this means, any intelligent person can soon become able to recognize the formations mapped with a good deal of certainty, and at least in a general way interpret the structure or "lay" of the rocks. Thus each person engaged in the search for ores can, to a large extent, become his own geologist.

It should be remembered that the zinc so far discovered in East Tennessee is near the top and the base of the Knox dolomite, which fact should determine the areas to be most closely prospected. So far as known, there is no ore in the middle part of the formation. It happens that there are geological maps published in folios of the U. S. Geological Survey, covering all the zinc area of East Tennessee.*

It must not be inferred that ore deposits occur in all faults, for many carry no ore at all, and none of considerable size carry ore throughout. The occurrence of ore at any point in or near a fault does not mean that it will be found at all other points, nor does the absence of ore at any point in a fault justify the conclusion that it is everywhere absent.

The fault plane is the plane of fracture. In prospecting, it is of the utmost importance to know the position of this plane, not only as to the direction of its extent with reference to the cardinal points, but also as to its direction downward. Both these things are shown in a general way on a geological map, and the structural sections that usually accompany such maps as regards the main faults. Many of the smaller faults are more important as ore producers than the larger ones. As it is impracticable for the geologist in public service to cover the ground closely enough to see all these, many escape his attention, or if seen are too small to be shown on the scale of his map. It therefore becomes of great importance for the prospector to find out where these are and to map them, if it is planned to prospect the ground.

Structures other than faults.—Ore may occur in other structural features than faults, such as near the axes of anticlines or of synclines, or in beds that have been fractured, regardless of whether they are folded or not. The significant thing in the occurrence is not so much in the structure, as in the fracturing that accompanied the rock movements. All prospectors in the East Tennessee zinc field have noticed that sphalerite occurs in rocks that are brecciated. That is, in rocks that have been much fractured and then recemented by sphalerite, or other minerals, such as dolomite, calcite, and barite. It follows that the occurrence of brecciated rocks in the Knox dolomite may well excite the interest of the prospector for zinc, though it can not be expected that all parts of a brecciated zone will be ore-bearing.

Prospecting for smithsonite.—As above stated, the zinc areas of East Tennessee are covered with a mantle of red clay, in most places many feet thick. Even the slopes are as a rule so covered, making rock outcrops uncommon. It is in this clay that most of the smithsonite occurs; but the ore does not often occur at or very near the surface, so that usually there is nothing on the soil surface to indicate whether it is present or absent beneath. As elsewhere stated in this bulletin, the usual absence

*These maps will be found in *Morristown folio* No. 27; *Maynardsville folio* No. 75, and *Greenville folio* No. 117. These folios may be had for 25 cents each, by sending to the Director, U. S. Geological Survey, Washington, D. C.

of the smithsonite from and near the surface probably is due to the carbon dioxide there present, which causes it to be dissolved. After having been thrown into solution, it is carried downward by the ground-water and reprecipitated in the positions above described.

At some points on the slopes where the clay is thinnest, the masses of smithsonite are but a few feet beneath the surface, and some mines have been discovered by chunks of it having been accidentally pulled up by the plow in cultivating the land. It is possible that in some such places careful observation by one who can readily recognize smithsonite, would result in the discovery of small fragments of that ore, and this would justify excavating for larger quantities beneath.

In prospecting, all streams should be carefully followed and such outcropping rocks as may be in their beds and on the slopes above, should be carefully examined for showings of zinc ore. Should ore be found in

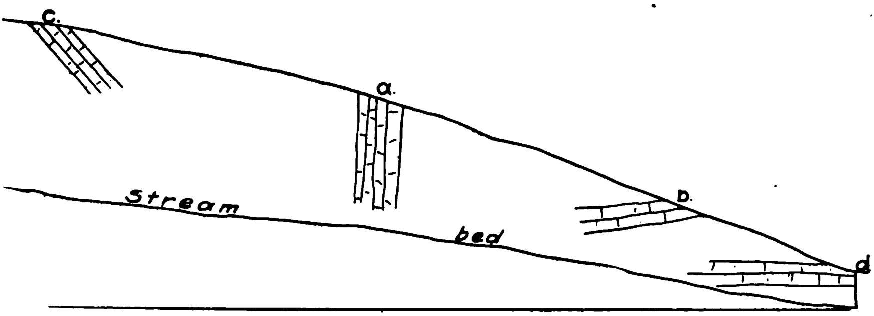

Fig. 6. Showing the position in the clay at which smithsonite shall be sought under different attitudes of the ore-bearing rock.

the stream beds, the chances are that it would be sphalerite; if on outcropping rocks of the slopes above, it most likely would be smithsonite. When such croppings are found, both the dip and the strike of the rock should be observed,* for the most probable direction of the ore hidden in the clay on the hills above the ravine, is along the strike. Whether the line of hidden ore will pass through the outcrop in the stream bed, or whether on the one side or the other, will depend upon the amount and direction of the dip. If, as shown in Fig. 6, the rock beds are perpendicular as at *a* the line in which ore might be found will be straight and will pass through the outcrop; if they dip in the direction of the beds indicated by *b*, the line will be crooked and will pass up over the hill to the right of the outcrop in the stream bed; if in the direction of those indicated by *c*, it will again be crooked, and will pass up over the hill to the

*It should be remembered that the strike is at right angles to the dip. For example, if the dip is northwest or southeast, the strike is northeast and southwest.

left of the outcrop in the stream bed. Should croppings at two points, as in two ravines, be located, these, by using the dips according to the instructions above, will locate the intervening area in which prospecting should be conducted. Should the rocks be level as shown at *d*, prospecting on hill slopes should be on a level with the outcrop in the stream bed. Under these conditions if it is desirable to prospect within the hill, the work can be done by driving tunnels, or with drills. To secure the most thorough investigation for the money expended, prospect holes and pits should not be put down in a straight line, but in a zig-zag. The width of the belt prospected will in each case have to be a matter of judgment. As most of the smithsonite is in the clay, it is well to remember that if the area to be prospected is on a slope, the ore in the upper part of the clay, owing to the downward creep of the soil, will be found somewhat further down the slope than the dip of the rocks would indicate.

The early method of prospecting in the clay was by pits and tunnels. This probably is the best method that could be used for the reason that it discloses the irregularities of the surface of the underlying stone, thus showing even to the prospector of but limited experience in these deposits, the most promising places in which to look for ore.

Prospecting for sphalerite.—While the smithsonite occurs mainly in the clay, the sphalerite is confined to cavity fillings and disseminated ore in the solid rock. The only places where this may be found exposed is in the rock outcrops of the slopes and stream beds. It must be remembered that if the ore on such outcrops is smithsonite, it will change to sphalerite, probably within a few inches of the surface. If it is found that the amount of ore thus exposed justifies it, prospecting may be done by the open quarry method; or, in case the overburden is great, tunneling or drilling may be resorted to. Should prospecting be done by driving tunnels, it is always well to observe the well known prospector's rule and "follow the ore" in the absence of expert advice. In case faults are encountered, as often will be the case, it is important carefully to determine their horizontal direction and dip, as well as whether the ore occurs on one or both sides of the fault. Only by such observations as this can one judge as to whether he should continue work under discouraging conditions, as when he strikes a "bar," "horse," or other barren spot in the rock.

The parts of the hills on either side of the ravines, in which sphalerite may be expected can be determined only by observing the strike and dip of the ore-bearing rocks, just as in the case of prospecting for smithsonite, as discussed above. Usually, on the divides away from the streams, the prospective ore deposits are so deep beneath the surface that prospecting by shafts or tunnels is out of the question, and drilling must be resorted to. The drill that has almost universally been used by the zinc prospectors in East Tennessee is the churn drill, but a diamond core drill has recently been successfully run by the American Zinc Company, at Mascot. The calyx drill, which is much cheaper than the diamond drill, probably would work in the zinc areas of East Tennessee with excellent results.

DESCRIPTION OF MINES AND PROSPECTS BY GROUPS.

HOLSTON RIVER GROUP.

Mossy Creek mine.—This mine is in the east edge of Jefferson City, to the east of Mossy Creek and 500 feet south of the Southern Railroad. The Osgood Exploration Company have been engaged in drilling and other development work since December, 1909. The formation in which the ore body occurs is the Knox dolomite, which here consists of beds of bluish-gray, compact, noncrystalline limestone and gray, partly magnesian limestone, both of which contain small amounts of nodular chert. The horizon at this locality, according to the areal geology of the Morristown folio, is near the top of the Knox formation.

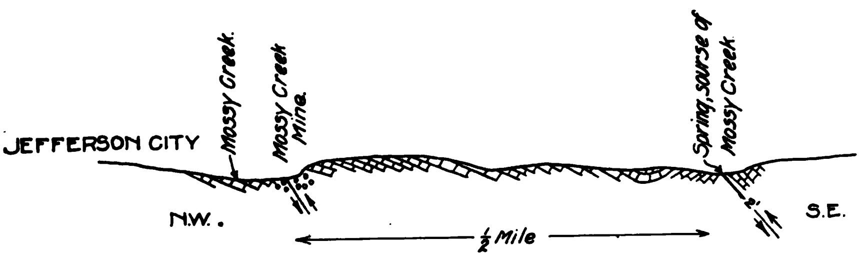

Fig. 7. General structural section of Mossy Creek mine.

A line of faulting runs north and south through the property, with the main fault apparently along the west side of the old mill. The upthrow is on the east side. The amount and direction of the hade could not be determined from field evidence, but the direction is more than likely to the east, inasmuch as that is the rule in this area.

Figure 7 shows the general structure at this mine. Almost 300 feet north of the old mill there is a small fault of at least several feet displacement, the upthrow being apparently on the southeast side. The direction of this fault is N. 60 degrees E. The limestone in this line of faulting is much fractured and brecciated.

The known ore body is roughly elliptical in shape, with the larger axis extending north and south a distance of 1,000 feet. The greatest width of the proven ore body is in the vicinity of the old mill, and it is here that most of the excavation work has been done. At this point, the ore body is at least 300 feet wide. Two hundred feet to the northeast of the mill there is an exposed vertical face of 50 feet of ore-bearing rock, and about 275 feet south of the mill there is an exposed vertical face of 75 feet of ore-bearing rock.

The pitch of the ore body most likely follows the fault plane, and as stated previously, it is believed that this hades to the east. The strike of the ore body apparently follows the general line of faulting. As shown in Fig. 8, the greater amount of the ore is to the east of the fault. A less amount is to its west.

The principal ore body occurs in the bed of semicrystalline, gray, magnesian limestone, the brecciated part of which is at least 75 feet thick. The bluish-gray, compact limestone, which is present in the slope above the old mill, is unbrecciated and contains no ore. To the west of the north-south fault is found a bluish-gray compact limestone, which is presumably the same as that on the slope above the mill. In the exposures in the pits to the west of the fault this bed has been metamorphosed into an

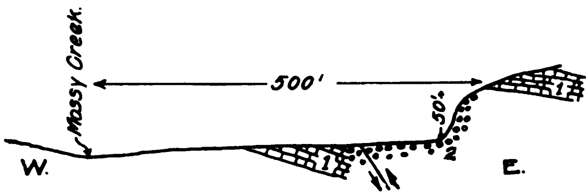

Fig. 8. East-west section, 50 feet south of the old mill, Mossy Creek.
1. Bluish-gray, compact, noncrystalline, magnesian limestone.
2. Semicrystalline, brecciated, magnesian limestone.

almost wholly crystalline dolomite, which within 150 feet of the fault and to the south of the mill, contains ore to a depth of 15 feet. To the north of the diagonal fault north of the mill, the rock formation is entirely the bluish-gray compact limestone, which is but little crystalline and possibly magnesian. However, it is brecciated and contains ore, but apparently in less amount than does the semicrystalline magnesian limestone to the south of this fault.

The minerals present in the joints and cementing the breccia are yellow sphalerite, associated with a considerable amount of white secondary dolomite, and a very small amount of white calcite. As a rule the veins of sphalerite are from one-fourth to one-half an inch thick. A small amount of cadmium sulphide, greenockite, occurs as a stain where the sphalerite has been partly altered. A little dendritic wad occurs in places as a coating on the magnesian limestone. Pyrite and barite were not observed even in the smallest amounts.

The secondary or oxidized ore is principally smithsonite, which is present in the red residual clay and as a coating on the uppermost few feet of rock. Only a small amount of calamine was observed. Below this zone of weathering, the ore is wholly yellow sphalerite. The mine is favorably located in that it is near the railroad and there is a good supply of water to be obtained in Mossy Creek.

According to Mr. S. W. Osgood, of the Osgood Exploration Company, Knoxville, Tennessee, this mine produced 13,432 tons of ore, from December, 1887, to June, 1889. The amounts of blende and carbonate ores were not given, but it is presumed that it was principally blende.

(H. D. Miser.)

Grasselli Chemical Company's mine.—The Grasselli Chemical Company, of Tennessee, is operating a mine about a mile east of the railroad station at New Market. The mine is located at the top of a low hill in an old field, south of the New Market-Jefferson City wagon road. The ore is all taken from residual clay of the Knox dolomite, and from the surface of the rocks beneath, and is recovered by both the open pit and the tunnel method of working. The pit is 300 yards long, and at the time of the writer's visit, probably would average 100 yards in width. The clay is removed with a steam shovel, and both the ore-bearing and the "dead" part are carted away. The appearance of the rock surface after the clay is removed is shown in Fig. 10. The tunnels are run from the bottoms of shafts, which are sunk into the pockets between the pinnacles of limestone. The shafts are located by putting down small holes with an auger, similar to a post-hole digger. This is manipulated by hand, with a rope working through a pulley hung to a tripod pole derrick, to discover where the pockets are. As the rock pinnacles occur without system, the tunnels of necessity run without plan, winding through pockets and around points of rock. Both shafts and tunnels must be well timbered, to support the great weight of clay, which in places is more than 60 feet thick. After a shaft and its tunnels are abandoned, some of the timbers are drawn, but most of them are left to rot and give way, causing numerous slips that show over the surface.

The management of the pit and underground work as well as that of the mill is excellent, and it is to this that the success of the mine is due. The ore is run through a "log-wash" to remove the clay, then in turn to the crushers, jigs, and finally over tables. That which passes over the tables is collected in slime-pits, which it is planned to work over when the pay dirt is exhausted.

The ore is smithsonite (carbonate) and occurs in the clay of the pockets between the pinnacles, on or only a short distance above the rock and on the sides and tops of the pinnacles. As only a small part of the clay is ore-bearing, the open pit method requires much dead work. Many of the pockets and pinnacles contain no ore, but in most cases, whether or

Fig. 9. Mossy Creek zinc mine, Jefferson City, Tennessee. (Osgood.)

Fig. 10. Open pit, Grasselli Chemical Company's mine, New Market, Tennessee. (Osgood.)

not ore is present can be determined only by removing the clay. The presence of the ore in any part of the clay seems to depend upon whether or not the former rocks above carried sphalerite. The rocks in the pockets that carry ore and the tops of the pinnacles that produce ore, usually contain veins of sphalerite, which seem to be the last small roots of the former richer deposits. The general appearance of these is shown in Fig. 12. The rocks beneath the pockets of barren or "dead" clay contain no such veins.

The richest deposits are in the pockets. Many of the tops of the pinnacles are quite rich, but the ore on the sides of the pinnacles is usually in thin scales on the rock surface, and must be removed with picks.

Fig. 11. Grasselli Chemical Company's mill, New Market, Tennessee. (Purdue.)

The rock is gray magnesian limestone in massive beds, between some of which are thin beds of shaly material, and between others, siliceous flinty ones. The siliceous beds contain disseminated sphalerite, but it is reported that they are not rich enough for ore. In the exposed parts of these beds the sphalerite has been dissolved out, leaving them full of small cavities, or "blossom". In parts, the limestone beds are much brecciated, the fragments having been cemented together with dolomite veins and sphalerite. These two minerals are mingled in such manner as to indicate that they were deposited contemporaneously. In parts of the veins the sphalerite is on one side, in others in the middle, and in others it is scattered through them. The same distribution of the ore and vein dolomite was noticed in all the Holston River group of mines.

As a rule, the ore of the veins is sphalerite, but in those rocks that are most decomposed, it is smithsonite. Such beds are so rotten that they can be dug out with the pick. The veins of smithsonite in the decayed beds, being less soluble than the beds themselves, stand out forming checkered surfaces. Large masses of smithsonite vein material are sometimes found with the rock all removed, leaving the smithsonite arranged in an interesting, honey-combed manner. For analyses of ores from this mine, see pp. 10 and 12. (A. H. Purdue.)

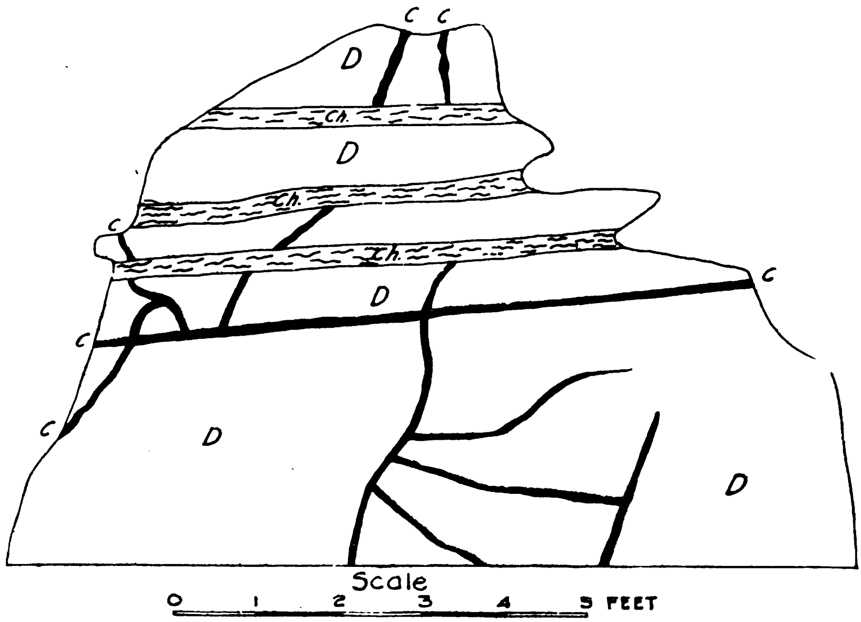

Fig. 12. Sketch of the top of a pinnacle, showing the occurrence of the ore.
C. Sphalerite.
D. Magnesian limestone.
Ch. Chert layers.

The chert layers are thought to be older than the ore veins. The joints in which the sphalerite occurs are attributed to shrinkage from dolomitization.

Open pit.—A mile east of south of the Grasselli mine, is an open pit 100 by 30 feet, in clay. The writer was informed that this pit produced 60 tons of smithsonite, the ore having been concentrated at the Tennessee Zinc Company's mill nearby. (A. H. Purdue.)

Tennessee Zinc Company's mine ("*Old mine.*").—This property is located two miles southeast of New Market, on the wagon road, and was worked as open cuts, of which there are two. The larger of these is 172 by 75 feet, and is said to be 70 feet deep. At the time of the writer's visit, it was filled with water to within 25 feet of the surface. The smaller pit is located 50 yards northwest of the larger one. Both are said to have produced a large amount of ore and to have been still productive when work was discontinued at the mine. Like the larger pit, the smaller one was well filled with water at the time visited.

The rocks dip 10 degrees S. 20 degrees E., and are mostly gray, massive, crystalline and noncrystalline magnesian limestone, though there is one bed 10 feet thick that is compact and dove-colored. The beds are much brecciated, but less so than those at the Grasselli mine. The ore is sphalerite, and is associated with dolomite veins. It is reported to have run from four and a half to six per cent of the rock quarried and to contain neither iron pyrite nor lead. As would be expected, the ore in the clay at the top of the pits, and that on the surface of the rocks, is smithsonite.

Ore was discovered on this property in 1894, and was prospected by John G. Long shortly after the discovery. It is reported that Mr. Long

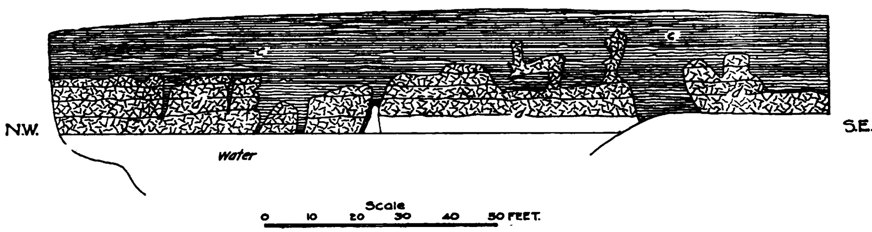

Fig. 13. Sketch at "Old mine," near New Market, Tenn.
c. Clay.
d. Fractured magnesian limestone.

shipped several car loads of smithsonite, taken from the clay. After the smithsonite of the pits was exhausted, Mr. Long induced the Ingalls Zinc Company, of Indiana, to take hold of the property. This company operated for three years, and then leased to Mr. Geo. Currens, who purchased the property in 1901, and operated it for one year. In 1902, Mr. Currens leased the property to the New Market Zinc Works, who operated it for six months. It then appears to have remained idle till 1907, when it was leased to Mr. Caswell Heine, of New York City, who prospected for one year and then bought the property under the name of The Tennessee Mineral Company. This company operated till January, 1911, when they leased to the American Zinc Company, of Tennessee, who operated till July, 1911, since which time no work has been done.

The property consists of 173 acres, and what appears to be a fairly good mill. As the area around the cuts is covered with a heavy mantle of clay, the most economical way of prospecting the property for further mining is by drilling.

American Zinc Company of Tennessee.—At present, the most active company in developing the zinc of East Tennessee, is the American Zinc Company of Tennessee, operating at Mascot, partly on property formerly owned by the Holston Zinc Company. The former company have operated as many as twelve prospect drills for several months, but do not wish the results of the drilling yet made known to the public.

The Holston Zinc Company secured most of its ore from a shaft, which is located at the top of the hill west of Big Flat Creek, and is said to be 170 feet deep, though this was not accessible at the time of the writer's visit. The American Zinc Company sank a second shaft, at the top of the hill, and 670 feet south of the old one. From the new shaft, ore was being secured at the 285-foot level. From the best information that could be had, the ore from the old shaft was secured from the 120-foot

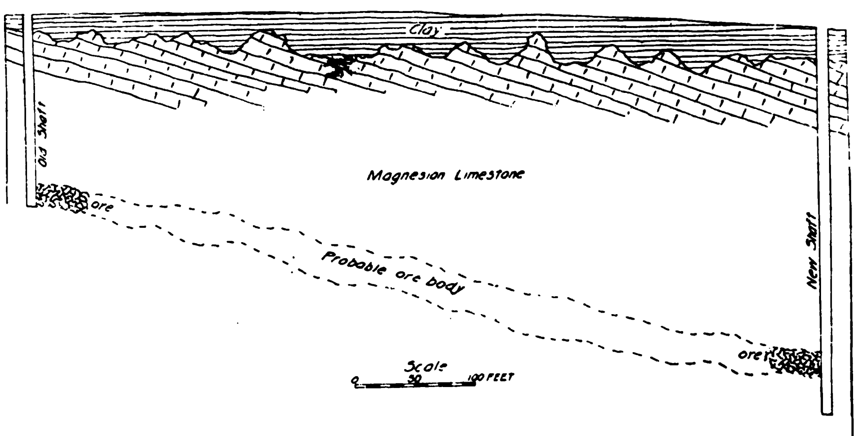

Fig. 14. Sketch showing the probably occurrence of the ore body at the American Company's mine, Mascot, Tennessee.

to the 160-foot level. As the rocks dip at an average of about 17 degrees south, it appears that the ore is confined to a rather definite horizon. In other words, it appears to occur everywhere in this locality in the same rock beds. Whether this is attributable to the ore having been originally deposited in these beds, or to them having been more fractured and consequently made better receptacles for ore than the beds above and below, is not known; but the evidence is in favor of the latter hypothesis.

Not all parts of the ore-producing beds are productive, nor even all parts of the brecciated portions. The veins in many parts contain no ore, being filled with dolomite and possibly some calcite. The richest parts appear to be those in which the fractures take the form of miniature faults, which, however, are prominent enough for the miners to speak of the rock on either side as the "foot" and "hanging" wall. In no case noticed were the displacements more than a few inches. In some of these little faults the ore was confined to one wall, and in others it occurred in both.

The ore is sphalerite of very light color. As has been stated elsewhere in this bulletin, a large per cent of the sphalerite on the dump of a Hoston River zinc mine will at first escape the attention of one accustomed to the ores of Missouri and Arkansas, on account of its bright color. Even when taken from beneath the level of ground-water, as in the case of the mine under description, the sphalerite is very light colored. An analysis of sphalerite from this mine occurs on p. 10.

The company has spent a large amount of money in prospecting the immediate territory about the shafts and from these eastward beyond

Fig. 15. Engine house and shaft, American Zinc Company, Mascot, Tenn. (Purdue.)

Mascot station. While those in authority are reticent about giving out information, the movements of the company and the good per cent of zinc in the rock of the dumps indicate that this locality contains a large body of ore, though much of it may be of such low grade that it can be worked with profit only on a large scale, with the use of the very best machinery, and under the most intelligent management that can be secured.

(A. H. Purdue.)

Open cut.—On the west bank of Big Flat Creek, 300 yards above the wagon bridge which spans the creek, near the railroad, there is an old working that has been abandoned for some years. It probably was worked by the Holston Zinc Company. The rocks are mainly dolomite, and dip S. 15 degrees. The cut is 100 feet into the hill, 60 feet wide, and 30 feet deep at the inner end. The beds are much brecciated and the ore is sphalerite, associated with vein dolomite, with smithsonite on the most weathered parts. As in "Old mine" of the Tennessee Zinc Company, the gray magnesian limestone beds contain compact, dove-colored ones that carry no ore.

(A. H. Purdue.)

Open pit.—One hundred and fifty yards north of the open cut above described, and on the opposite side of the creek, there is an old pit in clay that is reported to have produced a good deal of smithsonite. In mining,

Fig. 16. A brecciated pinnacle, common to the zinc pits of East Tennessee. (J. A. Ede.)

the clay was removed to the rock, which stands up as pinnacles like those in other pits of the area. These are brecciated and contain smithsonite on their surfaces. Some mining was done here by shafts and tunnels.

(A. H. Purdue.)

Open pits.—In the field east of the shaft of the American Zinc Company's property, there are three prospect pits, and a small open cut, the latter just south of the roadside. The pits were old and it could not be seen that they produced any ore, though small fragments of blue rock showed zinc "blossom," or cavities from which sphalerite had been removed from solution, thus indicating an ore body in the rocks beneath.

At the open cut, which evidently had been made two or three years, the rock thrown from the clay was full of a fine network of veins the thickness of a knife blade, which carry smithsonite.

(A. H. Purdue.)

Roseberry property.—The Roseberry property is located west of the creek by that name, between the wagon road and the railroad. The development consists of pit and open quarry work, and a shaft at the top of the hill.

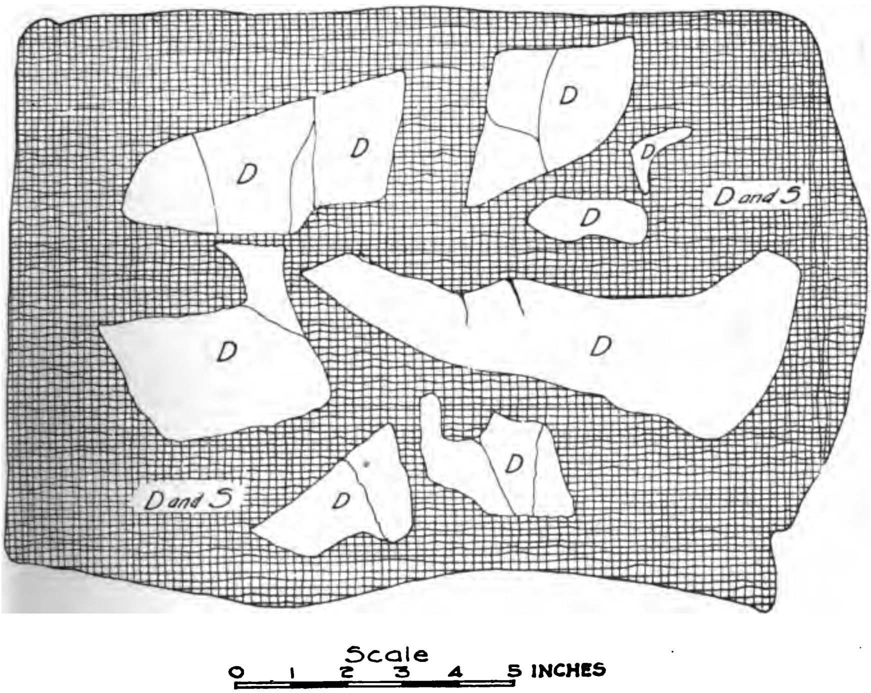

Fig. 17. Brecciated boulder at Roseberry mine.
D. Noncrystalline dolomite.
D. and S. Crystalline (secondary) dolomite and zinc blende.

The pit and quarry cover probably two acres. The clay removed from the pit was worked for smithsonite, and the quarry for sphalerite. The latter is 100 feet long and near the same width, with a depth of 30 feet. The rocks, where undisturbed, dip 15 degrees S. 20 degrees E., and consist of magnesian limestone containing secondary chert. Most of it has been extensively crushed and recemented with vein dolomite, calcite, and sphalerite, forming breccia. A part of the ore is disseminated, and occurs in secondary dolomite.

Sphalerite shows in abundance on the face of the quarry and of course passed into smithsonite at the contact of the rock and the overlying clay. The rock outcrops in places for a distance of 225 feet down the creek from the pit and quarry, and shows smithsonite.

The shaft at the top of the hill was not accessible at the time of the writer's visit, and but little information could be secured concerning it. It was reported to be 200 feet deep, but the small amount of material at the dump would indicate that it was much less. The dump contains a fair amount of sphalerite in brecciated dolomite.

A mill has been erected on the west bank of Roseberry Creek, but it has not been operated for some years. Just why mining should have been abandoned on this property is not evident, for the indications are

Fig. 18. Prospect drill, Roseberry property, Mascot, Tenn. (A. H. Purdue.)

such as to lead to the belief that it contains a large body of ore. In fact, from the evidence now obtainable, there is good reason to suspect a large deposit of low grade ore over much or all the ground from the open cut and pit above described on Big Flat Creek, to and including the Roseberry property.

(A. H. Purdue.)

Spout Hollow pit.—A half mile west of the Roseberry quarry, on the north side of the road, and on the east slope of Spout Hollow, there is a pit that covers nearly an acre. It has been abandoned several years. The deepest part is perhaps 25 feet, and in removing the clay, pinnacles were exposed like those elsewhere in this region. The ore rock and associated minerals are the same as those at the Roseberry property above described, except that the rocks are less brecciated, and consequently not so rich in ore. On the north side of the road, 300 yards to the east of the Spout Hollow pit, there is a pit in the clay from which smithsonite probably has been taken.

These pits are mentioned, not for their importance in themselves, but because they indicate the possible extent of workable sphalerite deposits beneath, along the general line connecting them with the Roseberry and Mascot property. (A. H. Purdue.)

McMillan pit.—This pit is located a half mile northeast of McMillan station, on the east side of the wagon road. It is an open cut 30 by 100 feet, extending N. 45 degrees E., into the hill. The rocks dip 30 degrees S. and 45 degrees E., and the long way of the cut follows the strike. The rock is gray magnesian limestone, much brecciated, though less so than in the mines about New Market and Mascot. The weathered parts contain a small amount of smithsonite and the unweathered part a like amount of sphalerite. The sphalerite is mostly in veins, but some of it is disseminated, and apparently is in a replacement of limestone. The rock, like that at the Roseberry property, contains a small amount of concretionary chert. (A. H. Purdue.)

O'Connor pit.—About one mile west of McMillan station, between the railroad and the wagon road, near the residence of Mr. J. A. Holt, there is a small open cut 10 by 25 feet, running east into the hill from the bottom of a small ravine. The ore is sphalerite and most of it is disseminatd in a bed of dark-gray secondary dolomite, though some occurs in breccia. (A. H. Purdue.)

Loves Creek prospect.—This property is on Loves Creek, about five miles northeast of Knoxville, and about one mile west of Caswell station, on the Bristol and Chattanooga branch of the Southern Railroad.

The rock formation exposed is the upper part of the Knox dolomite. The ore-bearing rock is brecciated, semicrystalline gray magnesian limestone, both above and below which are thick beds of bluish gray compact noncrystalline limestone. The strike here is about N. 45 degrees E. A small amount of chert is present in the limestone.

The ore-bearing bed, as well as those above and below, are very similar in character to that at the Mossy Creek mine at Jefferson City. This occurrence suggests that the ore-bearing beds at the two localities are really the same bed of magnesian limestone. Direct evidence tending to show the possible existence of a fault at this prospect was not observed.

To the west of the creek the ore-bearing rocks outcrop for a distance of 75 feet at right angles to the strike, indicating that the ore body is between 50 and 60 feet thick. In the openings on the east side of the creek, ore is present for a distance of about 130 feet at right angles to the strike, yet much of this interval does not contain ore, and it is estimated that the ore is not present in more than 100 feet of this distance.

Sphalerite is the principal zinc mineral for the reason that the prospected ore body is near the underground water level. Loves Creek is only a few feet below the open cuts. Hence the ore as shown in the cuts is near the lower limit of oxidation. The sphalerite occurs as vein filling, having been deposited in the cracks and cavities between the rock fragments. In many instances the magnesian limestone is partly replaced by the sphalerite along the veins. White calcite and white dolomite, often with a pinkish tint are the principal minerals associated with the sphalerite, the dolomite occurring in greatest amount. A very small amount of pyrite is present, and in places near the surface there is some calamine.

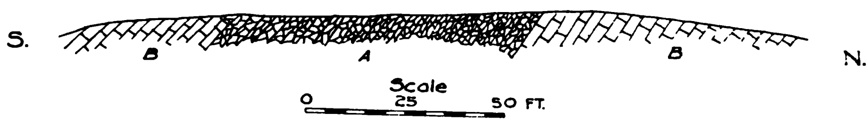

Fig. 19. Structural section on west side of Loves Creek, showing position of ore bed.
A. Semicrystalline, fractured and brecciated magnesian limestone.
B. Noncrystalline bluish limestone.

The prospect work here consists of open cuts, three shafts and a drill hole. However, at the time of the writer's visit, the shafts were caved in, and the record of the drill hole was not obtained. The first was done about 30 years ago, and about eight years ago A. G. Buffet, of Knoxville, put down a drill hole on the property. John D. Williams, of New York, did some surface work during 1909. (H. D. Miser.)

Gallion prospect.—This prospect is on Woods Creek, one-half mile northeast of Caswell station, on the Bristol and Chattanooga branch of the Southern Railroad. The prospecting has been in the upper part of the Knox dolomite, which is here bluish-gray, compact, noncrystalline limestone. No evidences of faulting were observed, but the limestone is more or less brecciated, fractured and dolomitized.

Work on this property was done five or six years ago by a Mr. Gallion, who made four shallow pits into the clay and magnesian limestone. At the time of the writer's visit, the pits were filled up to such an extent that rock exposures could be seen only in the sides of three of them. No ore was seen in place. Some ore nearby was stated to have been taken from them.

The ore is yellow sphalerite, which with pinkish dolomite and a small amount of white calcite, forms the cavity filling between the breccia fragments. The ore is very similar in its nature to that at Loves Creek.

(H. D. Miser.)

POWELL RIVER GROUP.

Snider property.—This property is located a mile and a half south of Powell River, six miles northwest of New Tazewell, and two miles west of the Knoxville, Cumberland Gap and Louisville Railroad. It is on a small stream known as Slate Creek, in a steep-sided ravine. The opening is 600 feet lower than the wagon road, on the crest of the ridge to the southeast.

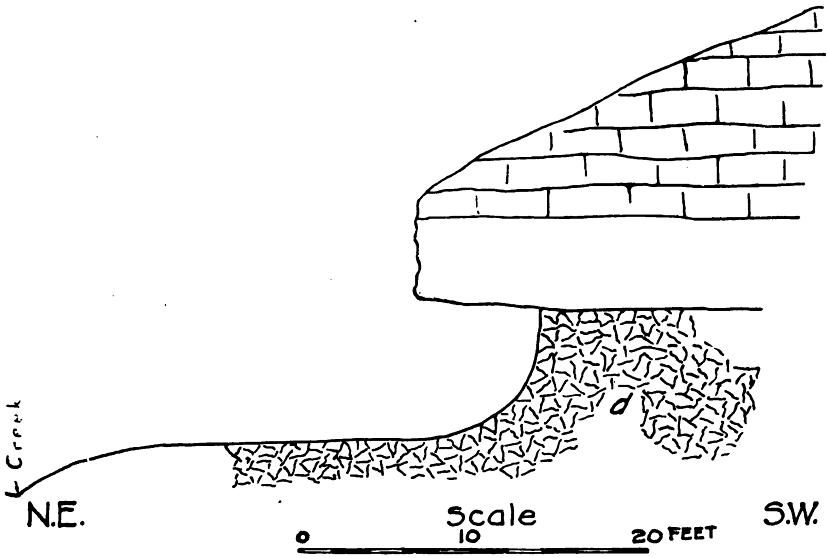

Fig. 20. Section at the open cut, Snider property.
d. Fractured dolomite carrying ore.

The prospect was opened up in 1902, by a man named O'Hara, from Kentucky, and was sold by him to J. T. Snider and son, who live in the immediate locality. These men worked at the development of the property at intervals for a year, during which time they sank a shaft 18 feet deep, in the bottom of the ravine, and opened up a cut 40 feet long, 10 feet wide, and 12 feet deep. At the time of the writer's visit, the shaft had filled with debris, but Mr. L. F. Snider reports that ore was found all the way from the top to the bottom.

The open cut was visible, but the walls were covered with dirt, so but little idea could be had of the amount of ore the rock contains. The rock carrying the ore is brecciated, finely crystalline, magnesian limestone that appears to lie horizontal, though the dip could not be definitely made out. There is no indication of faulting, but it is not improbable that horizontal shearing has taken place. The ore-bearing rock is quite brittle, and would crush easily.

The ore is galena, the sulphide of lead; cerussite, the carbonate of lead; sphalerite, the sulphide of zinc, and smithsonite, the carbonate of zinc. The galena and sphalerite are probably equal in amount. The cerussite and smithsonite exist in but small quantities, and probably would be found to disappear a short distance from the surface.

The associated minerals are pyrite, a sulphide of iron; vein dolomite, and greenockite, the sulphide of cadmium. The pyrite is mixed with the galena and sphalerite, usually in small crystals, but masses weighing several pounds are not infrequent. The greenockite occurs as a thin film on the magnesian limestone where the sphalerite is partly altered.

There are probably 20 tons of ore rock on the dump, taken from the open cut, and an equal amount taken from the shaft. This appears amply rich for milling. The stream flowing through the prospect would furnish water for a mill of small capacity. From the information gathered, it seems probable that a half-mile down the ravine, the stream becomes large enough to run a fair sized mill. A wagon road could be constructed down the ravine to Powell River, from which point there is said to be a good wagon road to the railroad. The hill slopes are covered with a thick growth of timber that could be utilized for mining and fuel purposes.

The indications of a paying body of ore at this prospect are sufficiently good to justify further prospecting.

(A. H. Purdue and H. D. Miser.)

Lynch property.—This property is located a mile and a half south of the Snider property, at the head of Sugar Creek, in a deep ravine, 400 feet lower than the road at the crest of the ridge to the south. The prospecting is reported to have been done in 1910 under the supervision of Mr. Clark, of Morristown, Tenn.

The development consists of two open pits, a shaft, and a tunnel. One of the pits is 40 feet long, with an average width of 20 feet, and the other is smaller. The rock lies nearly flat, and is gray, brittle much shattered magnesian limestone, like that at the Snider property. As at the latter place, much of the rock can be dug with a pick, only a small part having been cemented into breccia. The ores are of both lead and zinc. The lead ores are galena and a small amount of cerussite. Those of zinc are sphalerite, and a small amount of smithsonite. The amount of galena appears to be greater than the sphalerite. Pyrite

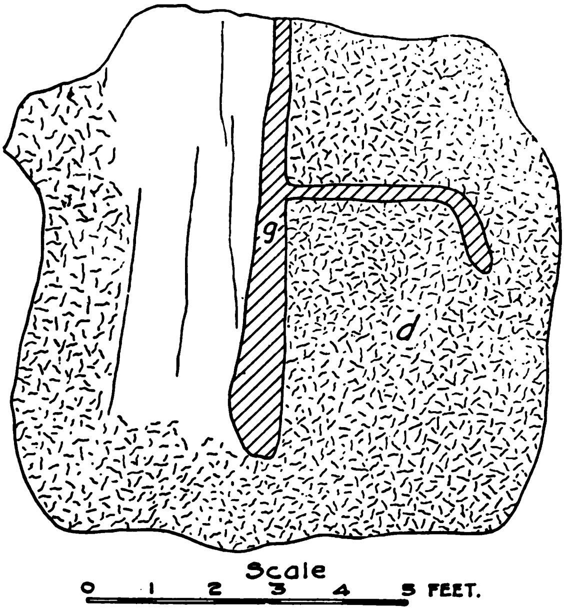

Fig. 21. A stringer of galena (g) in dolomite (d) at the Lynch property.

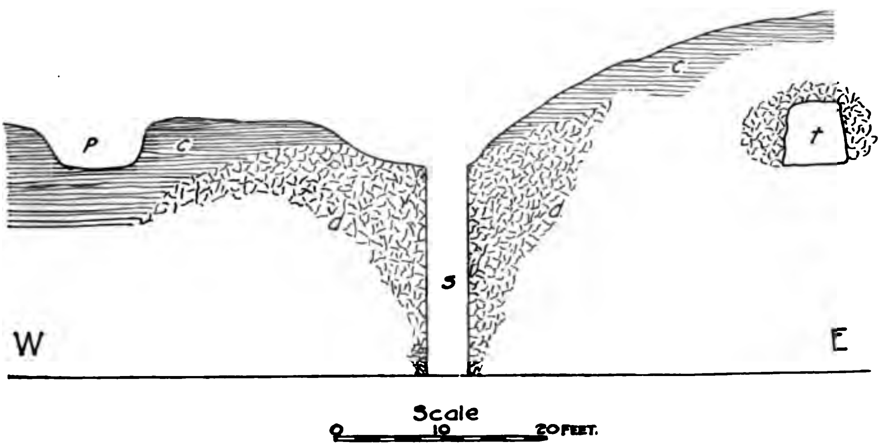

Fig. 22. Section, showing the development at the Lynch property.

d. Clay.
c. Fractured dolomite.
p. Pit.
t. Tunnel.
s. Shaft.

occurs rather abundantly, and is intimately mixed with galena and sphalerite in many hand specimens. Secondary dolomite occurs in small crystals and thin veins. Most of the ore is disseminated through the rock, but some of it occurs in thin stringers, as shown in Fig. 21.

The shaft is 20 feet deep from the bottom of the pit in which it occurs. It is in shattered dolomite, and contains ore sparingly all the way to the bottom. No ore was seen in the tunnel, though the inner end was full of water and was not accessible. The development of the property is shown in Fig. 22.

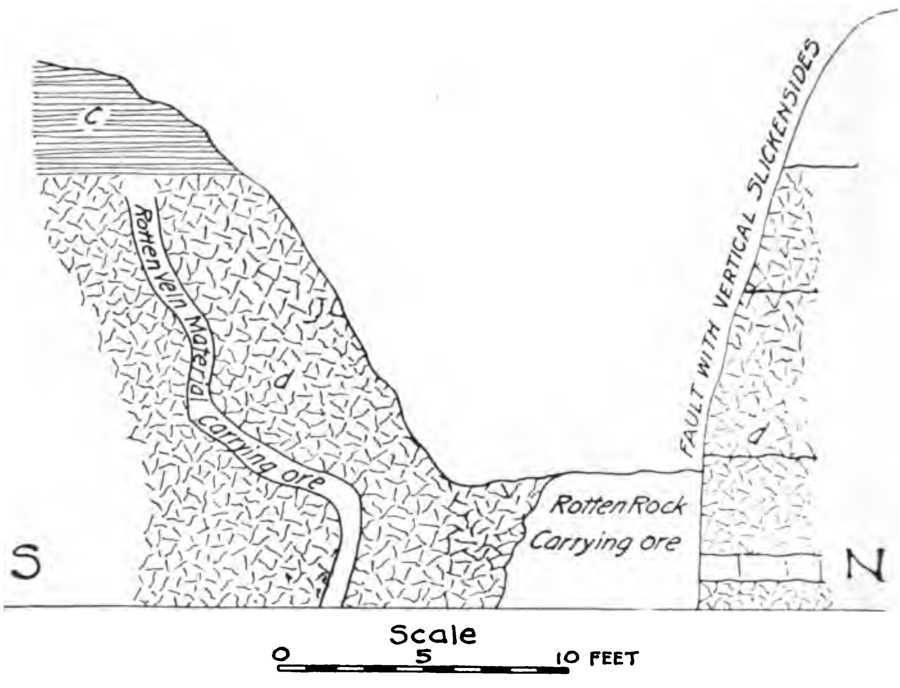

Fig. 23. Showing the ore relations at the Eli Goin property.
C. Clay.
D. Dolomite.

If this property should be worked, the ore can be hauled by building a road down Sugar Creek to Powell River, or up the creek to the road at the top of the ridge. There is enough timber near at hand for mining purposes, and enough water in the ravine to operate a small mill.

(A. H. Purdue and H. D. Miser.)

Eli Goin property.—This property could not be definitely located, but it is about one mile south of the residence of J. S. Lynch, a mile and a half west of south of the property last described, and a quarter of a mile nearly north of Newton Keck's home.

The development consists of an open pit 100 feet long and 20 feet wide, located near the head of a small ravine that runs down into a sink-hole about 500 yards west of the Eli Goin home, which is now abandoned. The rock is gray, brittle dolomite, like that at the Lynch and Snider properties, though more decayed. Most of the cut is in clay, though the rock is exposed near the inner end.

Figure 23 shows the rock structure and the manner of occurrence of the ore. In the development the open cut followed the fault. The conditions for the ore deposition were made possible by the faulting and accompanying fracturing of the work.

Apparently, the property had not been worked for some time previous to the writers' visit. Only a small amount of ore remained on the dump. Most of it was carbonate of zinc (smithsonite), but there was a small amount of carbonate of lead (cerussite). The absence of the unoxidized ores, galena and sphalerite, is due to the weathered condition of the rock. There is no water near at hand for milling purposes, but timber is abundant.

(A. H. Purdue and H. D. Miser.)

New Prospect mine.—This mine is located near the northeastern corner of Union County, a half-mile from the mouth of Hunting Creek, near what is known as Lead Mine Bend of Powell River. The development is shown in figures 24 and 25.

The ore occurs in a bed of massive, gray, brittle dolomite 50 feet thick. At first glance, the rock appears to be horizontally bedded, but closer examination shows that what appear to be bedding planes are shearing planes, dipping slightly to the north. Probably the most important horizontal shearing plane is in the floor of the mine, which dips to the east 10 feet in 100 feet. Except where roughened by solution, the floor of the mine is polished and distinctly slickensided, the slickensides running east and west, thus indicating the direction of the shearing movement. This shearing plane follows a bedding plane between the barren rock beneath and the ore-bearing rock above. The lower bed is hard, brittle, thinly laminated, dark-gray dolomite and is exposed near the west end of the open cut. This is the only continuous shearing plane. The others pass into each other, cutting the massive bed up into innumerable wedge-shaped pieces. These are insected by oblique smaller planes that dip mainly to the north, and intersect each other. Both sets can be detected as planes of shearing by their smooth surfaces and slickensides.

Besides the horizontal shearing planes, there are two that are nearly verticle, one on the north and one on the south side. The strike of these is east and west, and it is this that determined the direction of the ore body. Of the two, the shearing was much the more pronounced in the one on the north side, and for that reason it was followed in working the mine. Its faces are distinctly grooved and slickensided, these running parallel with the floor of the mine, which lies with the dip of the rock. The movement was not all in a single plane, but in several that are approximately parallel with each other and only a few inches apart.

The ore is sphalerite and galena, with their oxidized products, smithsonite and cerussite, the last two occurring in only small amounts. The accompanying minerals are dolomite in small amount and iron sulphide, which is probably pyrite, though it may be marcasite. The zinc and lead ores are closely associated, and much of the rock that has been mined is said to have run as high as 17 per cent ore. For analyses of smithsonite and sphalerite from this mine, see pp. 11 and 12.

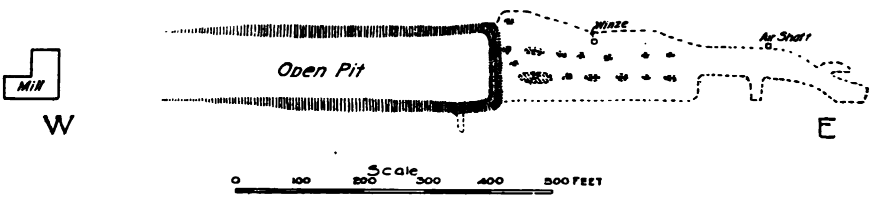

Fig. 24. Sketch, showing the plan of New Prospect mine.
P. Pillars.

The richest part is the lower 15 to 18 feet, where most of the shearing took place, and it is in this part that most of the mining has been done. The writer was informed by Mr. T. L. Davis, a miner of experience and a good observer, who has been about the mine for several years, that 30 feet of the rock above the part that has been extensively worked, carries ore of sufficient grade to mine with profit.

The effect of the vertical shearing planes upon the extent of the ore is one of the interesting features of this mine. Practically no ore occurs north of the north plane, and as well as may be judged, it rapidly becomes lean south of the south one. A winze, sunk from the bottom of the mine to the depth of 16 feet in the north plane, showed only a few inches of carbonate ore on either side of the plane. The 50-foot tunnel shown in Fig. 24 extending south from the open cut, produced a small amount of carbonate ore that occurred along a shearing plane, near the bottom.

The stripping at the top of the hill above the underground workings contained some carbonate ore, which probably was taken near the vertical shearing planes. The carbonate ore that came from the underground workings, occurred along shearing planes through which water had free access. In planes that are only a few inches apart, the ore in one may be carbonate and in the other blende, depending upon whether the plane was a water course or not.

The most promising parts of this deposit that remain to be mined are: (1) That just south of the south wall, or south vertical shearing

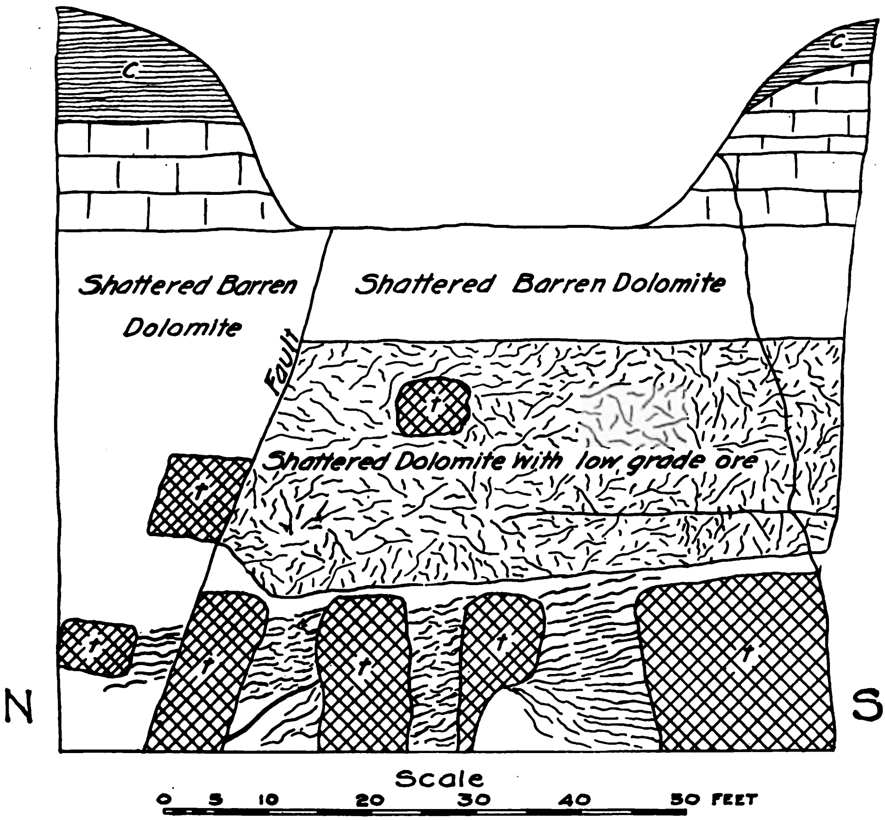

Fig. 25. Section at New Prospect mine, looking east from the open cut to where the underground work begins. The parallel lines show shearing planes.
c. Clay.
t. Tunnels.

plane, on a level with the present workings both in the open cut and in the underground workings. (2) The ground east and south of the inner end of the underground workings. The face of this part of the mine shows some very rich ore. Should there be a good body of pay ore east of the present face of the tunnel, it will lie between the Davis and Jarvis shafts, the location of which may be learned from those living in the vicinity. This ground should be prospected. (3) Most of the pillars are rich in galena and blende. (4) The 24 to 30 feet of rock above the present underground workings should be carefully sampled. If this is pay rock, it, with the ore that can reasonably be expected from the other parts mentioned, would make a large amount of workable material yet remaining in the mine.

According to Mr. T. L. Davis, of Sharps Chapel, this mine was opened in 1883, by Squires and Manning, of New York. These men hauled the ore to Powell River and shipped by water to Clinton, Tennessee, and from there by rail to New York. They worked the mine till 1888. About 1889, the property was taken over by the Eades

Fig. 26. New Prospect mine at inner end of open cut. (J. A. Ede.)

Mixter and Heald Zinc Company. This company built the first mill, which consisted of a crusher and a hand jig, in 1890. The present mill was built in 1891. It has eight jigs, with a capacity of 100 tons. The company operated the mine till 1897. In 1899, the property was leased to the American Metals Company, of New York City, who worked it till 1901. Since 1901, it has not been operated, except for three weeks in 1903, by a man named Jos. D. Hardin, but who shipped no ore.

While the Eades, Mixter and Heald Zinc Company was operating, the ore was shipped to Clinton, Tennessee, where it was smelted. The American Metals and Mining Company shipped their ore to Marion, Indiana. A part of it was shipped by water to Clinton, and from there by rail, and a part was hauled in wagons to Caswell station, on the Cumberland Gap and Louisville Railroad. Approximately 1,000 barge loads of concentrates are said to have been shipped by river, averaging 65 tons to the barge. The amount hauled by wagon to the railroad was not ascertained.

Three shafts have been sunk east of the mine, and the information that these afford will be of great value in the future working of the property. These are known as the Davis shafts Nos. 1 and 2 and the Jarvis shaft. Their location can be learned from those living in the vicinity. According to Mr. Davis, shaft No. 1 is 83 feet deep, with a 25-foot drift to the northwest, at the bottom. No zinc was found in the solid rock, but a loose boulder of sphalerite was taken from the clay at the depth of 27 feet. In shaft No. 2, disseminated blende was struck on the south side, at the depth of 40 feet, the ore rock being two inches thick. The other shaft was sunk under the direction of Professor R. P. Jarvis, of the University of Tennessee, who writes the following statement concerning it: "This shaft was sunk to a depth of 72 feet. For most of the distance it passed through stiff, red clay, similar to the material called 'buck-fat' by the miner, and commonly associated with the carbonate zinc ores of this region. No carbonate ores were found in the shaft, and while work did not proceed very far in the dolomite after this was struck, none was found in this, but we had not reached a point quite deep enough to catch the ore horizon in the old open cut and incline." (A. H. Purdue.)

Russell pit.—About 300 yards S. 70 degrees W. of New Prospect mine on the opposite side of the road from Mr. Newton Stiner's house, there is an open pit in clay, that was worked several years ago. It is 40 by 50 feet, and 18 feet deep at the inner end. In the sides, projecting through the clay, are numerous masses of much brecciated dolomite. This pit is reported to have produced 500 tons of carbonate ore. (A. H. Purdue.)

Caldwell prospect.—This prospect is located in "Lead Mine Bend" of Powell River, and about two and a half miles northeast of New Prospect mine and on the opposite side of the river from it.

The formation at this locality is the Knox dolomite. The magnesian limestone is bluish-gray, compact, noncrystalline stone which is near the base of the formation and resembles the magnesian limestone at the New Prospect mine.

The rocks lie practically horizontal. The beds are much jointed, the strike of the principal joints run N. 70 degrees W. Judging from exposures, no faulting with vertical displacement has taken place here, nor were evidences of horizontal displacement observed, though the limestone is much fractured.

The ore body is apparently associated with the main line of jointing. The four places where it has been prospected cover a distance of more than 500 feet and are in a line running N. 70 degrees W. There are no surface exposures to indicate the width of the ore-bearing rock.

The prospect work at this property consists of two shafts, a trench and a drill hole. The drill hole was put down to a depth of 25 feet on the left bank and near the water's edge of Powell River. Nothing was learned as to whether or not ore was found in the hole. About 165 feet S. 70 degrees E. of this hole is an old caved-in shaft. The writer examined some nearby ore which was said to have been taken from this shaft. It consisted of mixed yellow zinc blende and galena in large amounts, filling the cracks of brecciated magnesian limestone The marked peculiarity of this galena is that it seldom possesses vertical cleavage, but instead has an uneven fracture. The blende resembles that at the New Prospect mine. About 175 feet S. 70 degrees E. from the shaft and on the hill slope, there are some small trenches in the shallow residual clay from which a small amount of smithsonite has been taken. Then about 200 feet further up the slope, and 60 or 70 feet above Powell River, is still another abandoned shaft from which galena, sphalerite and smithsonite were taken, if we may judge from the presence of these ores on the dump.

In order to market the ore it would be necessary to float it down Powell River or haul it over wagon roads a distance of at least 15 miles to New Tazewell. The country is much broken and heavily timbered.

It is locally reported that the prospect work at this place was done by men, who, in order to be exempt from military service during the Civil War, manufactured bullets from the ore which they mined. The property is known as the Caldwell property, for the reason that a man by this name was one of the principal prospectors. Little prospect work has been done since the Civil War. (H. D. Miser.)

Shofner prospect.—This prospect is about one mile N. 70 degrees W. from the Caldwell place. The prospect is in Williams Hollow, three-fourths of a mile north of Powell River and on an east hill slope. The mineral rights belong to Isaac Shofner, of Sharps Chapel, Tennessee, who did the prospect work during the summer of 1911. The land is owned by Paris Walker, of Goin, Tennessee.

The rock formation is the Knox dolomite, and at this, as in the other localities of the vicinity the horizon exposed is near the base of the formation. Here the magnesian limestone is gray, much fractured, and lies practically horizontal. Considerable chert is mixed with the residual clay on the slopes. There is probably some faulting at this prospect. The ore veins strike N. 70 degrees W., and are apparently in line with the Caldwell prospect. For this reason it is thought that the two localities may be in the same line of jointing or faulting of the rocks.

The prospect work consists of three small open cuts at different elevations on the hill slope. Each of these cuts is four to six feet wide, and contains a vein of ore from two to twelve inches wide. The pitch of the veins is almost vertical. The zinc minerals are yellow sphalerite and smithsonite, associated with a small amount of galena, and occur as the cementing materials of fine breccia. A small amount of pyrite is present. (H. D. Miser.)

John Keck prospect.—This property is located near Goin and is owned by John Keck, of Goin, Claiborne County. The writer did not visit the locality, but obtained two specimens of ore from Henry Bostic, of Goin, Tennessee, which are said to have been taken from Mr. Keck's prospect. The rock with which the ore is associated is finely crystalline, gray, brecciated magnesian limestone. In one specimen there is a small amount of galena associated with calamine, dolomite, and considerable barite. The second specimen contains a high percentage of rosin jack and galena, the former in the greater amount. Associated with these minerals there are small amounts of smithsonite, dolomite and crystalline greenockite. (H. D. Miser.)

STRAIGHT CREEK GROUP.

Straight Creek mine.—This mine is located on Straight Creek, in Claiborne County, four miles west of Lone Mountain station on the Knoxville, Cumberland Gap and Louisville Railroad, and four and a half miles southwest of New Tazewell, on the same road. The Tennessee Zinc Company, Library Building, Cincinnati, Ohio, are reported to have a lease on the property.

The formation in which the ore body occurs is the basal part of the Knox dolomite, which is here bluish-gray, compact limestone, the layers of which are usually massive. The ore body is associated with a large fault which strikes N. 80 degrees E., and hades 63 degrees S. 10 degrees E. The fault may be followed for a distance of two miles to the west from the mine by a line of sink-holes, and it is reported that these extend a mile to the east. The accompanying sketch (Fig. 27), shows the structure at this mine.

The limestone on the upthrown side of the principal fault is more or less brecciated and dolomitized for a distance of six feet from the fault plane. Beyond this distance the limestone is more or less fractured for a distance reaching 40 feet. It weathers into bright red clay which is several feet deep even on the slopes, and makes surface prospecting difficult.

The ore body has been prospected along its outcrop on the south hill slope for a distance of about a quarter of a mile. For probably half this distance zinc carbonate, with a small amount of blende has been mined in frequent open cuts and by means of shafts. For the remainder of this distance there are occasional shafts and cuts from which zinc carbonate and a small amount of blende were taken.

At the time of the writer's visit, the mine was idle. Much of the timbering was rotten and had fallen in and the lowest workings were filled with water. Hence a personal examination of the form of the ore body was impossible.* The lower limit of oxidation is near the level of the inner end of the tunnel. For this reason carbonate and silicate ores are the principal ores in the over-head slope and the sulphide ores prevail below.

Yellowish-gray sphalerite is the principal sulphide ore. The section in Fig. 27 shows a width of six feet of high grade ore in the hanging

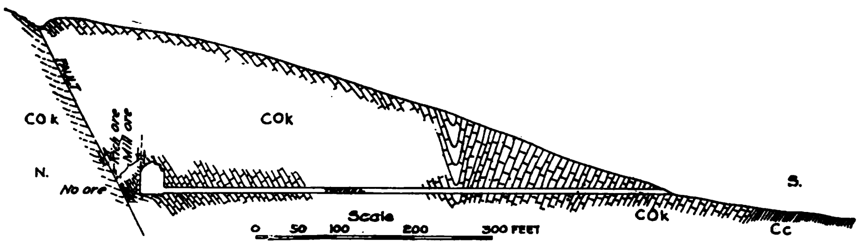

Fig. 27. Section of Straight Creek mine running N. 30 degrees W.
COK. Knox dolomite.
Cc. Conasauga shale.

wall next to the principal fault plane. Adjacent to this there is a lower grade of ore known as "mill ore" about 45 feet wide. However, this condition cannot be relied upon as general. It is said that the width of the brecciated and fractured rock in the hanging-wall is usually 30 feet; and it is in such brecciated and fractured rock that the ore is found principally as replacement veins. No ore is known in the foot-wall. Galena is frequently associated, intermixed with the zinc ores, and a considerable amount of pyrite is present.

The oxidized ores are smithsonite, calamine, and hydrozincite, the last of which is present in but small amount. Greenockite is not infrequently found as a yellow stain on the magnesian limestone. A great amount of limonite is common on the dump. Calcite occurs only as recently formed thin crusts on the rocks in the mine. The writer noticed

*A brief description of this is given by Watson *Trans. Amer. Inst. Min. Eng.*, Vol. XXXVI, p. 726

on the dump a large fragment of coarsely crystalline onyx marble without banding structure. Dolomite of white color is sparingly associated with the ores. An analysis of smithsonite from this mine occurs of p. 12.

The mine is within four miles of Lone Mountain station, four and a half miles of New Tazewell and five miles of Clinch River. The wagon roads are hilly and extremely muddy during wet weather. Straight Creek and the mine itself furnish an abundance of water for milling. An underground stream runs through the lower workings of the mine, and issues as a spring on Burch Creek, two miles to the west. The spring is on or near the fault, which passes through this mine. It is stated that the spring ceases to flow when all the water is pumped from the mine.

The main development at the Straight Creek property consists of a tunnel six feet wide and seven and a half feet high, driven N. 30 degrees W. from the base of the hill until it intersects the ore body; and a drift 15 feet wide, driven 300 feet west and 240 feet east of the inner end of the tunnel. In the east drift, ore was mined through a width of 30 feet and an incline was sunk 30 feet below the level of the tunnel. A mill is located near the entrance to the tunnel and is equipped with hoisters, pumps, crusher, jigs, tables, an engine, and three boilers.

The first work at this locality was done about 30 years ago. At that time carbonate ore was mined at the west end of the cut on the outcrop of the ore body, but no mill was erected. The ore was hauled to Clinch River, five miles away, and thence boated to Clinton, Tennessee, where it was smelted. Later the property was sold to a Mr. Richburg, who sank a 90-foot shaft about the middle of the cut on the hill slope. Carbonate ore was mined, and as before was boated on Clinch River to Clinton, Tennessee. Later the Eades, Mixter and Heald Zinc Company bought the property from Mr. Richburg. This company established a plant, consisting of a crusher, hand jigs and rolls, and drove the present entrance tunnel. They mined blende and carbonate ores, which were hauled to Lone Mountain station, and were thence shipped to Clinton, Tennessee. A car of galena was shipped by this company. It is said, that this is the only shipment of lead ore from this locality.

The present improvements were erected about 1906 by the Tennessee Zinc Company, of Cincinnati, Ohio. Operations were carried on for two years by this company, since which time the plant has remained idle. As in previous operations, the ore was hauled to Lone Mountain.

(H. D. Miser.)

This mine was visited by the writer, in company with H. D. Miser. It was impracticable for the former to spend more than a short time in the mine, but the following is taken from his notes: The development consists of a tunnel about 700 feet long, driven into the hill from near the base, and running N. 30 degrees W. The worked part occurs in a series of beds that dip 43 degrees nearly south. There is evidence of great shearing, some of the surfaces along the bedding planes having been thoroughly polished by this movement.

The mine had not been worked for some years, and but little of it was accessible. A few feet west of the inner end of the tunnel, the timber had fallen in so as to obstruct the passage, but we were told by Mr. A. Thacker, who was in charge of the mine, that it had been worked for a distance of 300 feet west and about 200 feet east of the inner end of the tunnel. The worked part is on or parallel with the fault mapped by the U. S. Geological Survey in the Maynardville folio. The width of the worked ground is from 20 to 30 feet, and as well as could be made out, the height is 30 feet or more above the tunnel. The part east of the tunnel contained water, so that it was not easily accessible.

Incident to the shearing, there was much crushing of the rock beds, and in the fractures thus produced, the ore collected, forming the breccia or ore rock. The ore in the upper part consisted chiefly of the carbonates of zinc and lead, while in the lower part it was reported as sulphides. The ore here appears to be an example of downward enrichment. We were told that the deposit was located from the "blossom" along the fault at the surface.

Mr. Thacker stated that at the bottom of the incline where the water stands, east of the tunnel, the ore changes its dip from 43 degrees S. to nearly level. Whether this is due to the change in direction of the rock fracturing or to change in the dip of the rocks, was not made out.

There is good reason for thinking that there still remains a large body of ore here, both overhead the present worked ground and below it, as well as along the strike of the fault beyond the ends of the present workings. (A. H. Purdue.)

Other openings.—The Tennessee Zinc Company has made a cut and sunk a shaft one-half mile east of the Straight Creek mine. The prospecting here is likely on the fault which passes through the mine. The limestone is folded, as is evidenced by the presence of a slickensided face. To the north of this face there is a 20-foot bed of brecciated rock. The direction of this bed is N. 80 degrees E., and its dip is practically vertical.

The opening in the hill slope is 35 feet long. The shaft, which is 25 feet deep, has been sunk at the lower end of the opening and is 60 feet above Straight Creek. The brecciated rock is exposed 25 feet on the slope below the shaft.

The ore-bearing rock is said to be six feet wide. The ores are smithsonite and yellow blende, principally the latter. The blende is present as veins in the breccia. Some pyrite is associated with the ore and small amounts of white dolomite and greenockite are present.

(H. D. Miser.)

W. F. Burch prospect.—This property is on Burch Creek, two miles west of the Straight Creek mine, six miles west of Lone Mountain and six and a half miles southwest of New Tazewell. The horizon is near the base of the Knox dolomite, which is here compact bluish-gray limestone. The prospects are near the fault which passes through the Straight Creek mine.

This locality was first prospected in 1892 by the American Association, which company sank a shaft and made a small open cut. This work was followed by that of Snow and Moore, who sank an additional shaft and made another small cut. The ore was hand sorted, and one and a half cars of such ore were hauled to Lone Mountain, from where it was shipped. It is stated that work at this prospect ceased in 1892, because of the panic at that time.

At the time of the writer's visit in December, 1911, the workings had caved and filled to such an extent that little could be learned with reference to the character and extent of the ore body. A mass of high-grade yellow sphalerite several inches thick was noticed, mixed with some smithsonite in a bed of limestone in one of the open cuts

(H. D. Miser.)

G. L. Phelps prospect No. 1.—This prospect is on the hill slope south of Straight Creek, one-half mile east of the Straight Creek mine, and three and a half miles west of Lone Mountain. The formation is the Knox dolomite, and as in the other deposits of the locality, the horizon is near the base The beds exposed are gray, compact, magnesian limestone, somewhat brecciated. It is not known whether the fault here is the same as that on which the Straight Creek mine is located, but it apparently is not. The strike of the fault is N. 80 degrees E., and the hade is 45 to 47 degrees N. 10 degrees W.

A shaft eight by eight feet and 15 feet deep has been sunk into the faulted zone. The top of the shaft is 40 feet (aneroid) above Straight Creek. From this shaft two tons of sphalerite ore and one ton of smithsonite are reported to have been taken An open cut 50 feet long from which some smithsonite has been taken has been made on the slope below the shaft. The ore is yellowish-gray sphalerite, associated with much pyrite and occurs in a vein a foot wide, in brecciated rock The smithsonite is present near the surface, is porous, and is stained with iron oxide.

(H. D. Miser.)

G. L. Phelps prospect No. 2.—This prospect is on the south hill slope north of Straight Creek and north of prospect No. 1. There are at this place three old prospects which are in a line bearing N. 80 degrees E. and cover a distance of 1,000 feet. At the time of the writer's visit in December, 1911, these prospects were filled to such an extent that but little could be learned with reference to the size of the ore body. It is stated that smithsonite in small amounts was taken from all three openings, and that some galena was taken from the opening fartherest west.

(H. D. Miser.)

THE FELKNOR MINE.

This mine is in Jefferson County, three miles southwest of Leadvale and the same distance a most south of White Pine, both of which places are stations on the Morristown and Paint Rock branch of the Southern Railroad. The mine is located at the top of a divide, one and a half miles from French Broad River. At the time of the writer's visit, December, 1911, the lower workings were filled with water.

The development work at this locality is in the upper layers of the Knox dolomite. This is interbedded with compact, light to dark, bluish-gray, laminated limestone and magnesian limestone. The latter in places has been changed to coarsely crystalline, dark colored dolomite. The magnesian limestone here contains a small amount of white quartz nodules, which are arranged in layers parallel to the bedding planes.

The structure is that of a monocline which dips to the south, and which has been disturbed by a fault with a horizontal displacement, as is shown by horizontal slickensides in one of the shafts. The fault plane is almost vertical, and has a strike of S. 60 degrees W. The brecciation of the rocks, which occurs principally on the north of the fault, is very marked. The magnesian limestone fragments lie in all sorts of positions, and a few large blocks are upturned so that they stand at a high angle The extremely brecciated part of the rock is at leas 200 feet long and 75 feet wide, but fracturing of the magnesian limestone prevails over a much larger area. Figure 28 is a general structural section through this mine and shows the relation of the ore body to the faulting.

The ore body is more or less irregular n outline, the longer direction being S. 60 degrees W. It has been prospected by means of pits, shafts, tunnels, and open cuts for a distance of about 400 feet. As would be expected, the ore is present in greatest amounts where the rocks are brecciated, but it is more or less irregular in its occurrence even in the breccia.

The ground-water level is at 'east 55 feet below the surface. For this reason the ores are partly oxidized the entire depth to which prospecting has been carried. Yellow sphalerite and galena are intermixed and are present in probably equal amounts. They occur mainly as fissure fillings in brecciated rock. In places they have replaced the magnesian limestone for short distances from the fissure walls. In one spot the sphalerite is associated with considerable pyrite and is black-jack. Some calamine is present, some of which has an oolitic structure. Each of the spherules has the radiate structure characteristic of this mineral. A small amount of hydrozincite is associated with the calamine. It is stated that galena was dug out of the residual clay within a distance of 200 feet north of the open cut and that an 8-ton mass of galena was found here.

When the mine was in operation several years ago, the galena was hand sorted from the sphalerite. It was then smelted near the mine and marketed. Some concentrates, the character and amount of which

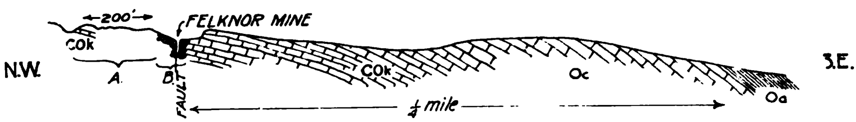

Fig. 28. Structural section through the Felknor mine, showing the relation of the ore body to the faulting.
COK. Knox dolomite.
Oc. Chickamauga limestone.
Oa. Athens shale.

are not known, have been shipped from the mine. However, galena was the principal ore marketed, and as a result there is near the mine, a pile of about 600 tons of apparently high-grade b!ende ore with a considerable amount of galena, which could not be hand sorted.

(H. D. Miser.)

JEAROLDSTOWN GROUP.

Jearoldstown prospect.—This property is a quarter of a mile northeast of Jearoldstown, Green County, and 17 miles northeast of Limestone, a small town on the Br'stol and Chattanooga Branch of the Southern Railroad.

The horizon exposed here is the upper part of the Knox dolomite, which is at this locality bluish-gray and compact, noncrystalline 'imestone, crumpled into sharp, close fields. The limestone outcrops as large rounded masses which protrude through the thin mantle of residual clay and other material. This limestone has been burnt to lime, which was used locally.

The prospect work consists of two shafts which were sunk on or near the axis of an anticline. Figure 29 shows the structure at this locality, a short distance west of the shafts. At the time of the writer's visit in December, 1911, these shafts were filled to such an extent that no ore and little rock were seen in place. A few scattered fragments of brecciated, dolomitized limestone on the surface are stated to have been taken from the shafts. The cavity filling between the breccia fragments is white dolomite with a small amount of yellow sphalerite Pyrite was not observed, but a small amount of white barite is present on the dump. Lead ore is reported to have been found in this locality, though the writer saw none.

Barite is of frequent occurrence in the vicinity of Jearoldstown. It occurs as veins in the limestone, and has been mined on a small scale and marketed as barite flour.

(H. D. Miser.)

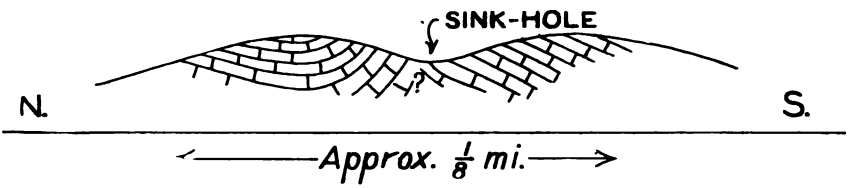

Fig. 29. Partial structural section of the hill northeast of Jearoldstown. It is the axis of this anticline which is prospected a short distance east of the locality of the section.

Dobbins farm prospect No. 1.—This prospect is two miles southwest of Jearoldstown Green County, and about 17 miles northwest of Limestone, a small town on the Bristol and Chattanooga Branch of the Southern Railroad, on a farm owned by Ed. Allen. The prospect is on a north hill slope and about 30 feet above a small branch.

A cut 50 feet long and eight to ten feet wide has been made in the magnesian limestone and clay and runs northeast-southwest at right angles to the slope and with the strike of the Knox dolomite. This is here gray, compact, semi crystalline, magnesian limestone, in which there is a little nodular chert. No evidences of faulting were observed. At the time of the writer's visit, the cut was partly filled with debris and other material, and no zinc ore was seen in place. A pile of ore five by six by two feet near the cut, is stated to have been found here. Practically all the ore in the pile is high-grade smithsonite, which is associated with a small amount of white barite. A vein of barite which varies from six to 18 nches thick, in the magnesian limestone was seen here. The work at this place was done more than twenty years ago

(H. D. Miser.)

Dobbins farm prospect No. 2—This prospect is a little more than a quarter of a mile south of prospect No. 1. It consists of a shaft which was sunk more than twenty years ago into the residual clay of the Knox dolomite. Since that time it has filled to a great extent and grown up with bushes and briers. A vein of gray barite a few inches thick and associated with much porous limonite was seen in place in the side of the shaft. The minerals on the old dump are white and gray barite, which are more or less porous; pyrite, and a considerable amount of porous limonite. No zinc ore was observed.

(H. D. Miser.)

FALL BRANCH GROUP.

Fall Branch mine.—This mine is on Fall Creek, in Sullivan County, two miles northeast of Fall Branch, Washington County, 10 miles southwest of Kingsport on the Carolina, Clinchfield and Ohio Railroad, and seven miles from Pactolus on the same railroad. The East Tennessee Mining Development Company, of Lima, Ohio, owns five acres of the property, and have a lease on other parts that have been prospected by them. Mr. W. B. Poling, Fall Branch, Tennessee, is superintendent of the mine.

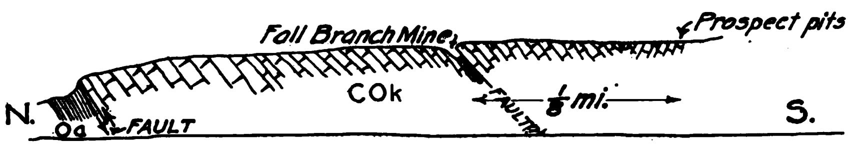

Fig. 30. Section in vicinity of Fall Branch mine, showing the apparent structure. (Not drawn to scale.)
Oa. Athens shale.
COK. Knox dolomite.

The formation exposed at the mine is the upper part of the Knox dolomite. It is here gray, semicrystalline magnesian limestone in and near the ore body. A short distance to the south of the ore body it is bluish-gray, compact, noncrystalline limestone, which is not known to be magnesian.

The structure at this mine, judging from the surface exposures, is monoclinal The ore body, which is a brecciated and fractured bed about seven and a half feet wide, coincides with the dip and strike of the magnesian limestone beds. It is said that, in an incline shaft which was not accessible, the hanging-wall is polished smooth and shows slickensides. Figure 30 is a sketch of the structure at this mine.

As stated in the preceding paragraph, the ore body is seven and a half feet wide and lies parallel to the bedding. The dip of the magnesian limestone at the mine is 45 degrees S. 60 degrees E. The ore minerals are present more or less persistently in the brecciated and fractured rock throughout the entire distance of about 1500 feet on the property. This distance has been prospected principally by means of pits and open cuts. An incline shaft 150 feet deep has been made at the mine and to the west of the creek a tunnel 230 feet long has been driven into the hill. Ore is said to exist the entire depth of the shaft, except for a distance of 25 feet on the upper part.

The level of the ground-water is near the creek which flows close to the mine, and for this reason the ores above the creek level are more or less oxidized. The sphalerite in places is black-jack; in others it is rosin-jack. It is associated with considerable white and pinkish dolomite and a small amount of calcite. Pyrite is fairly abundant in the wall rock and vein material. Barite occurs in small amounts as vein-filling mineral. However, it is thought its presence will not interfere with the development of the ore body, as it occurs in small, widely separated pockets. Chalcopyrite is present in the vein dolomite as small crystals. A dark, hydrocarbon compound is rather abundantly associated with the vein material in the workings at the mine. It occurs as veins in the vein filling materials and in places is disseminated through the vein material. This compound resembles graphite, but on being heated in a closed tube, it gives off gases and changes its appearance. For an analysis of sphalerite from this mine, see p. 10.

The oxidized minerals are smithsonite, calamine, limonite, and malachite. None of these occur in large amounts, and malachite was seen at only one place and then in a very small quantity.

The order of the deposition of the minerals appears to have been as follows: (1) Pyrite and sphalerite; (2) Dolomite; (3) Chalcopyrite, barite and calcite; and (4) (?) Hydrocarbon compound.

About one-eighth of a mile south of the mine are four small pits. Two of these are apparently on one vein of ore and the other two on a different vein. All show some blende which is associated with dolomite and calcite.

The first work at this place was done probably twenty years ago. At that time prospecting was being carried on for barite, and the zinc ore was discovered. A company mined and hauled two car loads of carbonate ore to Jonesboro on the Bristol and Chattanooga branch of the Southern Railroad, 18 miles distant. In 1906, the East Tennessee Mining Development Company began development work, and in 1908-09 installed a plant fitted with a 125-horsepower tandem engine, a Clifford dry concentrator, four sets of rolls, seven concentrating tables and one dryer. The plant is near Fall Creek, which furnished a good supply of water the year round. It is stated that on account of litigation, work was discontinued shortly after the mill was erected. The wagon roads to Pactolus, seven miles away, are said to be good.

(H. D. Miser.)

Merrill farm prospects.—These prospects are two miles northeast of Fall Branch and seven miles from Pactolus station on the Carolina, Clinchfield and Ohio Railroad. The prospected ore body is a northeastward continuation of the vein extensively prospected by the East Tennessee Mining Development Company. The strike is N. 40 degrees E., and the dip is to the southeast. Judging from the distance that the hanging and foot-walls are apart, the bed of fractured and brecciated rock is from five to six feet thick. It is prospected by frequent shafts, pits and one tunnel, all of which cover a distance of about a quarter of a mile. The principal shaft is on the hill northeast of the Fall Branch mine. It is said to pass through 100. feet of clay and then 50 feet into the rock below.

Some ore is present on the dump. It consists of blende and a small amount of smithsonite,an d is associated with white and pinkish dolomite in magnesian limestone. It resembles the ore at the Fall Branch mine, and consists mainly of black-jack associated with more or less dolomite and a considerable amount of iron sulphide and iron oxide. A small amount of barite occurs with these minerals. Black-jack, containing a large amount of pyrite, was taken from the tunnel on this property.

(H. D. Miser.)

Bowman prospect.—This prospect is one mile southwest of Bloomingdale, and is owned by Frank Bowman, of Kingsport, Tennessee. The writer did not visit this prospect, but the following information relating to it was supplied by Mr. W. B. Poling, superintendent of the Fall Branch mine:

The prospecting consists of a few pits and a shaft 120 feet deep, and was done in 1907 and subsequent years. The ore vein is claimed to be 12 feet wide. The character of the ore is similar to that at the Fall Branch mine, though it is somewhat darker in color.

(H. D. Miser.)

Wells prospects.—These prospects are near the crest of a ridge and are three and a half miles northeast of Fall Branch. The property is owned by J. W. Wells, Fall Branch, Tennessee.

The rock formation is the upper part of the Knox dolomite, which here strikes about N. 30 degrees E. and dips about 70 degrees S. 60 degrees E. There are no visible evidences of faulting at this locality. The prospect work consists of ten small pits, eight of which are apparently on the same ore-bearing bed of rock, which is brecciated and fractured magnesian limestone. This bed in places reaches a thickness of at least six feet. The eight prospects extend in practically a straight line for a distance of more than a quarter of a mile. The vein-filling and cementing material of the breccia fragments is dark rosin-jack, which is associated with white dolomite. Little smithsonite is present near the surface. A small amount of pyrite, scattering crystals of chalcopyrite, and a hydrocarbon compound occur in places. Barite was not observed to be associated with the ore. The other two pits, which are on the north slope of the hill, are very small, but both sphalerite and smithsonite are present in them.

(H. D. Miser.)

Cox prospect.—This prospect is on the top of a ridge three and a half miles northeast of Fall Branch on land owned by R. G. Cox of that place. The rock formation is the upper part of the Knox dolomite, which here strikes N. 25 degrees E. and stands almost on edge. The prospect is a small pit about 80 feet southwest of the pit fartherest to the southwest on the Wells farm. The shallow residual clay has been dug away from the rock, exposing the ore-bearing rock. The minerals are rosin-jack associated with much white dolomite and a small amount of barite.

(H. D. Miser.)

THE FUTURE OF ZINC MINING IN TENNESSEE.

While zinc mining in Tennessee has been carried on more or less intermittently for many years, it has never reached the proportions to class it with the important industries of the State. On account of this, general doubt has sprung up in the mind of the public as to the existence of zinc in commercial quantities, within the State; and the question is often dubiously asked: "Will zinc mining in Tennessee ever become an important industry?"

To this question, the writer would give the following answer: From the best that one can judge under the present conditions of development, the possibilities of the zinc industry in northeastern* Tennessee are large, providing those engaging in the industry use the greatest possible economy and employ the best engineering talent. The company that fails to observe either of these requirements is doomed to failure. The *talent* should carry with it not only thorough technical training, but also integrity, wide experience, and ingenuity in both mining and milling. The great degree of perfection that has been reached in the mechanical

*Zinc is reported as occurring south and west of Knoxville, but this Survey has not as yet investigated that area.

recovery of ore must be carried to the highest possible refinement in producing Tennessee zinc.

Mining for carbonate ore may be done on a small scale, but as a rule, mining for blende must be on a large one. In the prospecting and early development of a mine, competent advice regarding the geology of the ore will always save a great deal of unnecessary expense and often prevent failure.

The district contains an abundance of water, timber is not difficult to secure, coal and labor are cheap, and transportation facilities are good.

PUBLICATIONS OF GEOLOGICAL SURVEY OF TENNESSEE ISSUED.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.* To make it possible for libraries to complete their sets, and for persons having real need for any of the volumes to obtain the earlier ones at small cost, 500 copies of each report are reserved for sale, at the cost of printing, the receipts from the sales being turned into the State Treasury.

Gaps in the series of numbers are of reports still in preparation:

Bulletin No. 1—Geological Work in Tennessee:
- A. The establishment, purpose, object and methods of the State Geological Survey; by George H. Ashley, 33 pages, issued July, 1910; postage, 2 cents.
- B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

Bulletin No. 2—Preliminary Papers on the Mineral Resources of Tennessee, by George H. Ashley and others.
- A. Outline Introduction to the Mineral Resources of Tennessee, by George H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.
- D. The Marble of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.
- E. Oil Development in Tennessee, by M. J. Munn, issued January, 1911; 46 pages; postage, 2 cents.
- G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

Bulletin No. 3—Drainage Reclamation in Tennessee; 74 pages, issued July, 1910; postage, 3 cents.
- A. Drainage Problems in Tennessee, by George H. Ashley; pages 1-15; postage, 1 cent.
- B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.
- C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

Bulletin No. 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

Bulletin No. 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

Bulletin No. 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen, for sale only, price 15 cents.

Bulletin No. 10—Studies of the Forest of Tennessee.
- A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage, 3 cents.
- B. Chestnut in Tennessee, by W. W. Ashey, issued December, 1911; postage, 2 cents.

Bulletin No. 13—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley. issued May, 1911; 40 pages; postage, 2 cents.

Booklet—Resources of Tennessee in a Nutshell, by Geo. H. Ashley; 16 pages; issued, 1911.

"*The Resources of Tennessee*"—A monthly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2 cents a number.

PRINCIPAL PAPERS.

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